THE JOURNAL OF
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January, 1952 Vol. 42, No. 5

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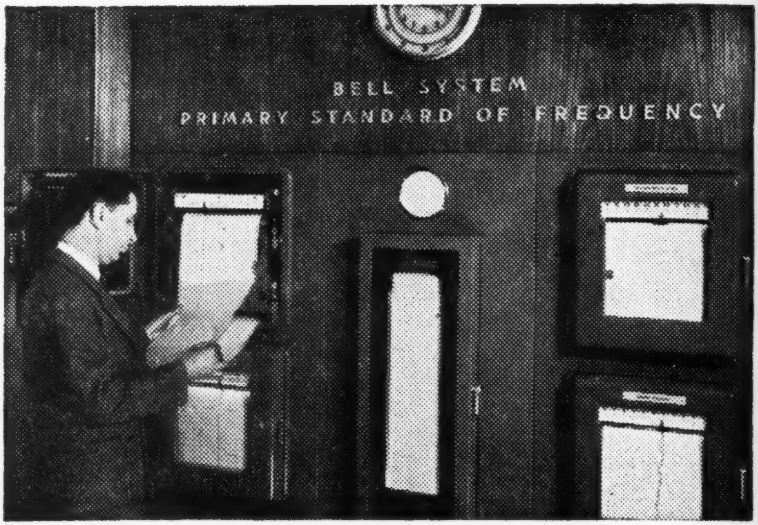
The American Society for Engineering Education



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Published monthly (except during July and August) at Prince and Lemon Sts., Lancaster, Pa., by the American Society for Engineering Education under the Supervision of the Publication Committee: A. B. Bronwell, Chairman, Northwestern University, S. C. Hollister, F. M. Dawson, C. E. Watson, Editor. Entered as second class matter, October 17, 1912, at the Post Office at Lancaster, Pa., under the Act of August 12, 1912. Subscription Price, $5.00 per year; Single Copies, $1.00.

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Report of Committee on Adequacy and Standards of Engineering Education

By S. C. HOLLISTER, *Chairman*, C. S. CROUSE, L. F. GRANT, and M. D. HOOVEN

Introduction

The aim of this report is to present at least in spirit the impressions of your committee concerning the adequacy of present-day engineering education and observations relating to what it estimates to be the standards employed by the engineering schools. Any attempt to appraise the present position of engineering education is destined to cause a certain amount of misunderstandings, due largely to the attitude of the reader at the time, and the impression the words convey in the climate provided by that attitude. Specific statements are often too limiting when taken literally, and generalizations are often too vague. An endeavor has been made, however, to present for consideration the committee's views on the present situation with the hope that, though brief and at times over-simplified and specific, the main observations will be accepted in their intended perspective.

Growth of Engineering Curricula

Engineering education in America was not developed after a preconceived plan. It evolved in parallel with the needs of a growing country, a country engaged in the development of a vast industrialization. From the first it filled a practical need, and its design emanated largely from an evaluation of the professional requirements.

There were only a half dozen schools of substantial merit by 1866. While the concept of engineering was the application of science to useful purposes, the educational program was heavily charged with the art of engineering practice. The better curricula had their roots in scientific studies. At that time, and for a generation to follow, a majority of practicing engineers were not engineering college graduates; they were men who through experience, observation and study, developed themselves to the point where they could cope with the technical problems of their time. Books began to appear and, with the development of laboratories for the teaching of principles (which, by the way, had been by 1870 in operation for 15 years in the Chemistry Department at the University of Michigan), gave strength to the program of the colleges in systematization of technical knowledge.

With the passage of the Morrill Act in 1862 the means and urge to found in each state a program in the mechanic arts for the aid of manufacturers were at hand. From 1870 to 1896 there was rapid expansion of the number of schools to 110 and the gradual formulation of the curriculum. By 1910 the forms of curricula in the older branches of the profession were pretty well standardized as to pattern. No elevating influences appeared to be at work on other than the newer curricula, such as chemical and metallurgical enginering, until the first World War.

Between the two World Wars the engineering schools developed programs in electronics. Although these and the newer pre-war programs were patterned after the "standard" form of curriculum, they nevertheless introduced new elements of strength in the increase of basic and applied science; and it was soon noticeable that they possessed more vitality and

potential than the older programs. Yet most schools did little or nothing about these older curricula. Instead, most colleges of engineering were preoccupied with the development of various offerings to cover students interested in the fringe areas: those who would be contiguous to, but not really a part of, engineering itself. While these programs served a useful need, their inclusion in one guise or other as *engineering* programs was a clear departure from the earlier concepts of professional training.

During the entire period from the earliest days to the second World War, there was not an established position for the technical school offering a program that would be post-high school, but with more emphasis on high-grade craftsmanship training than on professional education. Many of the earliest schools of this type gradually expanded to four-year programs. A few, having a clear view of the need and great importance of such training, have held to their convictions and have developed strong programs with notable results.

Critical Evaluation of Factors in Engineering College Development

As one examines the history of the growth of engineering colleges and their development, certain features thereof are especially evident. The very rapid expansion in both number and size of schools left little choice than to imitate the more successful. Not so obvious was an underlying situation that many of the new schools had only a dim concept of their objective in service to the profession. There was at work in the same setting the notion of spreading higher education for all, a factor that is restrictive of high standards. As schools grow, the pressure for staff expansion led to recruiting by the simple process of keeping on recent graduates, and then allowing them to do their graduate work, if any, while teaching. In this way, there was a subtle influence of continuity of curriculum with little urge for re-evaluation or vitality of concept of objectives. A standard pattern was achieved, not so much by deliberative process as by a sort of combination of gravitation and inertia.

Coupled with these influences was the circumstance of ever-pressing financial problems in young and growing schools, and the consequent limit on salary scales. Not a few administrators found themselves unable to pay salaries that would command talent already developed, and in some cases they could do little more than employ something less than the top of the currently graduating class—"temporarily." The deadening effect of obsolescence upon laboratory equipment, some of it hard-won after years of waiting and planning, had its part in gradual "standardization" through the lack of means to preserve a dynamic program.

Over the years, the number of practicing engineers without engineering college education was gradually diminishing. This was due in part to the availability of engineering schools, and to an increasing extent to the complicated nature of the engineering function. Between the World Wars, with the introduction in many schools of programs with greatly reduced scientific and technical content, yet calling the output "engineers," there arose increasing confusion as to what constituted engineering and what characterized engineers. Accountants, for example, and graduates of business courses, and others, who had enterprise to pose as consultants on managerial matters, called themselves management or industrial engineers. Graduates of such courses could perform but elementary engineering functions. There can be no question that these courses of reduced technical content were an aid to certain persons; the serious doubt was whether they should have been considered *engineering* courses.

From the earliest days the program of engineering education was limited to four years, in parallel with the usual undergraduate college program. A very few schools added one or two years, with an additional degree. During the period of development and growth, the medical, legal and architectural professions have

extended their length of program to meet their particular objectives. It is significant that these developments had no effect upon the engineering professional program and that in consequence, with conspicuously few exceptions, the engineering curricula have remained four years in length, beginning immediately after high school.

Meantime, the fields of sciences, without exception, have been obliged to extend their programs through the addition of graduate work. Today no scientist is considered adequately trained without the doctor's degree. Whether graduate work is an appropriate program for the professional engineer is one of the questions dealt with by your committee.

Probably the most significant single characteristic of the engineering educational field is that it has no generally accepted professional objective as a goal for the educational program. There is general agreement respecting the form of the curriculum. It is difficult to detect differences in programs between schools simply by comparison of curricula. The major differences lie in the depth of instruction and in the objective of each institution in respect of the professional outlook to be achieved. There exists today a spectrum of objectives ranging from highly professional programs supported by strong science backgrounds to vocational programs in which only a moderate amount of science is included.

It is possible to divide the subjects included in any engineering curriculum into five groups, as follows:

1. Basic science (mathematics, physics, chemistry, biology).

2. Applied science (mechanics, thermodynamics, fluid mechanics, geology, circuit theory, properties of engineering materials, etc.).

3. Applied engineering (for example, internal combustion engines, structures, machine design, industrial electronics, foundry technology, plant design, etc.).

4. Adminstrative and managerial (cost control, industrial organization, labor relations, etc.).

5. General (liberal courses, to provide a general educational background). Curricula may vary in the emphasis placed upon group, and in the extent of dominance of one group over the others.

Historically, applied engineering courses dominated the curriculum in the early years. Gradually the pattern of basic science courses was evolved and generally included. Shop courses were reduced to a minimum.. From 1885 until the first World War, mathematics was stabilized in the older curricula, terminating with the calculus. Since then only a few schools have carried the subject further in civil, chemical, mining, and mechanical engineering, while many schools have required additional mathematics in electrical engineering. Except in chemical engineering, and in some cases of mining engineering, the amount of chemistry required has been limited to general inorganic chemistry.

The time requirement in physics has remained nearly constant in most curricula since about 1885. Generally, the classical approach to physics instruction has been followed. The depth has varied with the amount of mathematics available at each stage. The calculus, while standard in all curricula, is not employed to the same degree in physics. In civil and mechanical engineering the amount of physics is limited to one year in most schools; and in many the same limit is found in electrical and chemical engineering. Generally, however, the approach from the point of view of atomic and molecular structure is needed but wanting.

The time devoted to mechanics is similar in nearly all schools. The variation in effectiveness of the course is not due to allotted time so much as to the depth of instruction. For many years it was the custom to minimize the use of the calculus in this subject. The development of stronger texts over the last two decades has greatly improved the effectiveness of the instruction; however, there is still much variation in depth of the requirements placed on the student. There may be said to be a definite upswing in the

quality of instruction in mechanics, although this it not believed to be general. In mechanical engineering, for example, vibrations and their consequences are treated in only a few schools. In fact, in civil engineering dynamics is regarded as being unnecessary, yet fatigue is becoming more important in structural design.

Hydraulics used to be taught from the empirical standpoint. Between the two wars there was pressure, emanating from the aeronautics field, for instruction in fluid mechanics. Some schools dealt sincerely with this proposed change; but many others simply changed the course name from hydraulics to fluid mechanics.

While in chemical engineering thermodynamics has been taught with regard to interaction between the thermal and chemical circumstances involved, there has been little attention given to such matters in mechanical engineering. Today, a chemical engineer is not infrequently better trained for fundamenal work in heat power than the mechanical engineer, in whose field heat power lies.

During the past several decades the instruction relating to engineering materials has developed into a program reciting a general discussion of their manufacture, and their mechanical properties as revealed by standard acceptance tests. The metallurgical aspects are lightly touched upon if at all. Instances can be found of the absence of a course in materials in electrical engineering, while in other cases in the same field students get the notion that such instruction together with the mechanics of materials is largely unnecessary for an electrical engineer, especially in communications.

Factors of Major Significance in Curriculum Design

Many perplexing problems stem from the fact that the engineering college, in preparing students for professional work that will reach maximum culmination twenty or more years hence, must evaluate hazily discernible future events. It certainly appears desirable that a major stress be placed upon those elements of the curriculum that will give the most continuous and lasting support to the graduate's professional life. Apart from the teaching of the professional attitude toward engineering and the instilling of the engineering and scientific method of attack upon problems, there are certain specific features of the curriculum that can be accepted as most essential.

The first of these has to do with courses least likely to obsolesce. While it is necessary to give a certain amount of instruction relating to the present state of the art, it is certain that the present state will change, and hence that time given to such courses is not time devoted to a subject of sustaining value. Sifting back through the curriculum, it seems clear that instruction in the basic sciences, if taught in a manner such that knowledge of them makes available working tools, contributes the most sustaining part of the curriculum. Among these basic sciences, the greatest potential for future development in science and technology is to be found in mathematics. An engineer with a good knowledge of mathematics is in a position to read with understanding and profit in physics and chemistry. Likewise, as his interest and need may expand, he may read further in the applied sciences, such as mechanics, elastic stability, advanced thermodynamics or fluid mechanics. Similarly, new applications of sciences to engineering situations may be understood and assimilated. Thus, mathematics not only becomes the support of the group of courses that will obsolesce least; it becomes the means of further technical growth as befits the graduate's interest and need. Building into the program in this and other means for further technical self-development of the individual after graduation is the second most important feature of a well-designed curriculum.

The third feature that impresses your committee as of ranking importance has to do with the way in which the applied courses are related to those in basic and applied science. Two distinct approaches

are discernible in present practices: one utilizes the engineering situations provided in the applied courses to illustrate the manner of employing the sciences in engineering work, while the other makes the applied courses the goal of the curriculum with the minimum of application of the sciences. The former builds into the student a power of analysis and resolution in engineering situations that permits a wide range of application. The latter tends toward the achievement of a series of skills intended to equip the student for specific jobs immediately upon, and soon after, graduation. The first is professional preparation, the second vocational training. What is involved is not alone the way in which individual courses are presented; it especially relates to the prevailing concept of the function of the whole curriculum.

Following the concept that the differentiating characteristic of the engineering function is the ability to utilize the sciences for the creative process of design and development of useful apparatus, structures or other works, the program should aim at the development and expansion of the imaginative process of creative thought. Engineering educational processes are most commonly of the problem type, requiring but a single answer, with no latitude for judgement, and no imaginativeness beyond the visualization of the circumstance of the problem. Programs in architecture far surpass those in engineering in this respect. We tend toward producing a literal-mindedness that is not compatible with creative imagination.

The foregoing discussion has been in broad terms. It is believed that quantitative specifications for engineering curricula are not adequate as guides to curriculum planning because they tend toward regimentation, toward fixation, and toward eventual stagnation of awareness of the professional needs. The content in each of the five categories enumerated above must be determined in terms of the need of the graduate two or three decades ahead, not in specific detail but in sound skeletal preparation, with most of the details to be filled in through further study and acquisition of experience in the field. The skeletal program must be strong and of sufficient stature to support and sustain the growing professional career.

Engineering is both a science and an art. A balance between both is desirable. The tendency has been to emphasize the art unduly. The "engineering approach" can be presented in the manner in which science is brought to bear on an engineering situation. Much of the art can better be acquired in the field. Industry is coming quite generally to recognize this arrangement as desirable for its needs.

Suggested Program

The quality of engineering curricula varies over a wide range, from highly developed professional programs to those having a predominantly vocational content. The foregoing discussion relates especially to the middle and lower portion of the range. Accrediting procedures relate almost entirely to the minimum standards, and tend to breed complacency among those schools that just barely satisfy such a standard. While accrediting must be maintained as a part of the licensing procedure, it cannot be expected that accrediting of itself will achieve the improvement of schools that satisfy the minimum requirements—unless two or more classes of schools were established and accrediting set up for each class. Your committee believes that such a scheme would neither be welcome nor desirable. Rather it believes that the engineering educational field has a great opportunity to study itself, with the object of finding ways at all levels to improve its service to the profession.

One way to make such a study is to set up an agency that would study and report its findings, as was done by the Society for the Promotion of Engineering Education in the Twenties, under the late W. E.

Wickenden.[1] Such a procedure has the effect of isolating the study, and removing it from the schools themselves. The conclusions of Wickenden, written in 1929, are to be found in Appendix I of this report; and your committee is struck with the potency of the statement to today's situation, and the extent of the failure of the schools to implement much of the recommendations. Other statements, appearing since the Wickenden Report and bearing upon the same subject, are given in the remaining appendices.[2] From these it seems clear to your committee that what is now needed is active study and self-appraisal by the schools themselves, looking toward implementation of recommendations already made.

In some quarters the suggestion has been made that an overlay of graduate work is the answer to a need for stronger science content in the curriculum, and to a higher total level of achievement. Your committee believes that the basic program in engineering leading to the first degree in the field should be of a quality to suffice for the professional need of perhaps eighty percent of the graduates, and that truly graduate work should be reserved for the remaining few having special competence. The responsibility for support of the profession, it is believed, must rest chiefly upon the adequacy of the undergraduate program.

[1] "The American Scene," by W. E. Wickenden, Director, Investigation of Engineering Education, *SPEE*, Vol. I (1929), p. 1000.

[2] (*a*) "Engineering and Social Progress," by Karl T. Compton, *Proceedings, SPEE*, Vol. XLVII (1939), p. 8.

(*b*) "Atomic Engineering?," by Theodore von Kármán, *Mechanical Engineering*, October, 1945, p. 672.

(*c*) "Tomorrow's Engineers," by J. R. Van Pelt, Excerpt from *Proceedings, ASEE*, Vol. 55 (1948), p. 168.

(*d*) "Present-day Engineering and Applied Science"; Report of Panel on the McKay Bequest, Harvard University (1950), p. 7.

The great pressure upon the engineering schools to provide general education in addition to an increased scientific and technical training brings them constantly face to face with the limitation in time imposed by the conventional curriculum. It is perhaps time that this problem was approached in terms of total need; and then the time required to achieve this need be measured beginning with the preparation now available from the secondary schools. For many years the approach has been to see what can be given within the four-year framework, with the result of over-crowding the program and with a general shifting first in one direction and then another without total gain in achievement. Other professions have had to face this issue. If engineering maintains professional stature, it will have to organize accordingly. Some have suggested a pre-engineering period in which the high school preparation may, if necessary, be augmented to a desired level before beginning engineering study.

There has been some discussion of the list of degrees granted in engineering. There is a gradual tendency to drop the professional degrees of C.E., M.E., etc., awarded after a suitable interval of practical experience and the submission of an acceptable thesis. If the professional degrees became generally available for work in course, they could then be used to designate the longer programs that are now under way, whether they be one-degree or two-degree programs.

Finally, it becomes clear that there is going to be a shortage of engineers for many years to come. At such a time, in the national interest, it is of paramount importance that the best possible education in engineering be provided by our schools. Each man is going to be called upon to cover a greater range than heretofore, if the engineering needs are to be met. Every school should devote itself to ways of substantial improvement of its program, to the end that its graduates will meet the responsibilities being placed upon them.

Cooperative Relationships Between Engineering Colleges and Secondary Schools

By GEORGE K. DREHER

Executive Director of the Foundry Educational Foundation

A Starting Point

A typical engineering approach requires that we first identify the problem and then gather the facts before a solution can be sought. In secondary school—engineering college cooperation, the same formula can apply. This paper is presented as one case. It is an attempt to identify a few of the road blocks and facts which prevent the full alignment of educational forces toward the solution of the shortage of engineering graduates.

The opportunity to tackle this secondary school angle came about as a friendly criticism of engineering college practices by representatives of the Cleveland High School system. This criticism was promptly answered by Dean S. C. Hollister (President of the American Society for Engineering Education) during a special visit to Cleveland and in a meeting attended by many high school principals and representatives of the Cleveland Guidance and Placement Counselling service under the Staff Direction of Miss Mildred Hickman.

This, then, is to be an analysis of the situation in Cleveland. Many of these points probably apply in all major secondary school systems. The facts in this history lead to certain recommendations which we will cover a bit later.

The Cleveland High Schools

First of all let us just take a brief look at the Cleveland secondary school establishment. Of direct interest to engineers is the fact that the male graduating classes beginning in 1922 when 997 young men completed their high school work, did show constant increases up to a peak in 1939 of 3853. Since that time, with the exception of one odd year, this number has steadily dropped to 1897 in 1951. During the years 1945 through June of 1951, inclusive, some 4878 boys enrolled in Colleges out of a total of 16,099 male graduates. This represents 30.3% of the male high school population. A good share of this total was due to the fact that during this period 2907 of these graduates were GI's who qualified for high school diplomas and who thereafter had educational rights under the GI program.

1271 of this graduating group entered engineering study. This represents 7.85% of the male graduating class. Fenn College and Case Institute of Technology, with Ohio State University a good third, received the major portion of this group. Against the College entrants this represented 26% for engineering (a very high proportion over the seven year period). In this summary one high school, East Technical, sent 20% of its graduates (⅖'s of its College entrants) into engineering college. A good share of this is due to the guidance effected by East Technical's principal, Mr. Bernard Taylor. His curriculum has gradually evolved so as to permit organized preparation for engineering study.

The engineering college percentage for the 12 eligible schools varies from a low of .19% to the 20% just mentioned. The following chart shows present trends.

FIVE HIGH SCHOOLS SHOWING HIGHEST ENGINEERING INTEREST (COLLINWOOD, EAST HIGH, EAST TECHNICAL, MARSHALL, WEST HIGH). REPRESENTING 83% OF ENGINEERING COLLEGE ENTRANTS FROM THE ENTIRE TWELVE CLEVELAND HIGH SCHOOLS

Subject	1945–1951 (Incl.) Averages	1951 Alone	
Average Male Graduates	987	786	(80% of average)
Average Males to College	321	250	(78% of average)
Average Males to Engineering College	151	82	(54% of average)
Per Cent of Engineering/High School Graduates	15.3%	10.4%	

The Cleveland school system is proud of its student mortality record as compared to national averages. They state that the national mortality record of high school students is in the neighborhood of 50%. In Cleveland it is a good 10% higher being 55% for the boys and 65% for the girls. There are several conditions aiding this high school mortality at the present time. Some of the defense plants are offering high wages for men without any training. In Cleveland, for the past many years, the building trades have been especially lucrative with the average carpenter, plumber, brick mason and electrician earning far in excess of the published averages for engineering, or for that matter for college students.

The industrial nature of the city of Cleveland, itself, makes its population predominantly of industrial workers. While many families wish that a College education might be arranged for their children, the fact remains that in most cases the inspiration and caliber of family training is not such as to lead a young man along the rigorous mental path necessary for successful college careers. Another factor is the lack of finances. Military service is a deterrent and we believe that many young men join directly from high school through purely emotional factors and with the hope that the much advertised education offered in the various branches will somehow prepare them for civilian life later on.

I might add, at this point, that engineering is not the only field suffering under the present circumstances. Young girls with a very slight amount of typing and shorthand instruction are being urged to leave school by Cleveland industry and take positions in their offices and we might add, at lucrative salary levels from $200.00 and up.

In its guidance and placement activity the Cleveland school system, of course, does have some policies. Prominent among these is the one which states that they will not recruit students for any specific field of study. They will guide the interests and wishes of students and their parents. At the same time, however, they indicate a willingness to cooperate with universities and other agencies attempting to sell their school or their field of endeavor. From our viewpoint, this includes the engineering colleges and the Engineering Societies as represented by the Cleveland Technical Societies Council. The Cleveland schools seek to avoid the exploitation of their students by any group which includes the professions.

Road Blocks

In addition to the above policies there is a certain reluctance to push engineering. There are several listed reasons for this, but prominent among them must be placed the fact that there are very few engineers in secondary education and that practically all of the Counseling work is accomplished from the viewpoint of the schools of Education and Liberal Arts. The following points are more specific, however, and we will list them with some discussion point by point:

1. Forcing of Mortality.

There still persists a knowledge of the fact that many colleges and universities did, in the recent past, deliberately force

the mortality of a certain percentage of their entering classes.

2. The Publicized Mortality of Engineering Students.

So much attention has been given to this in engineering discussions that the student, family and counselor's minds are more or less conditioned to the fact that the student has an only 1 in 2 chance of finishing an engineering curriculum. Actually, comparative figures with other college entrants show that engineering is only slightly tougher in this respect. We might add that the Cleveland school system was remarkably pleased with the analysis which Case Institute of Technology made of their own student success history. These results showed a 76% survival of the entering freshman with one-third of the mortality due to academic reasons.

3. The Handling of Entering Freshmen.

The transition from the relatively closely guided career in high school to the entirely "On your Own" technique which has prevailed in engineering and other colleges is to much for many young and immature minds to absorb. Guidance of the individual student and lack of friendly counsel by faculty members tends to leave the young man rather high and dry. He needs someone to coach him through the first few months.

4. The Tough College Professor.

Within the past year a pair of Professors in the presence of a Cleveland school representative and during a discussion as to the failure of a couple of Cleveland boys made reference to the fact that a certain Professor considered it his duty to flunk a certain number each year.

5. Better Admissions Procedure.

The schools feel that admissions procedures should be of the type that would insure a better than 50% success among the entering students.

The secondary school educators are much closer to the families of these young men and are frequently criticized for the financial sacrifice engendered by the failure of a young man in college.

6. Gaps.

It must be acknowledged that some gaps exist between the level of teaching in mathematics, physics, chemistry, English and college expectancy. In Cleveland, the schools do not claim to have their courses in these subjects accurately tuned to the varying interpretations of standard requirements made by individual engineering colleges. A similar situation existed in 1940 among the young women students who sought careers in the nursing professions. The failures in this group were close to the 50% level. Through the cooperation of Professor Margene O. Faddis at the Francis Payne Bolton School of Nursing, Western Reserve University and Dr. Herschel B. Grime, Supervisor of Mathematics in the Cleveland Public Schools, a book was published by the J. B. Lippincott Company entitled "The Mathematics of Solutions and Dosage, including Simple Arithmetic." This book was intended as a guide to the high school teacher and as a practice manual for the entering student nurse and has served as a bridge between the high school and college level studies in that field.

7. Stature of High School Educators.

A high school educator has many feelings akin to those possessed by college educators. They are forced to keep their students in class through high school. This does not change their thinking about the fact that washouts in college reflect upon their teaching ability as well as upon the various abilities of the guidance counselors, principals and other personnel in the system. They enjoy the success of their students just the same as do engineering educators and they are depressed by the failures.

8. The Report of the U. S. Bureau of Labor Statistics.

In spite of the fact that a retraction and new set of charts were published and that *Life* magazine ran a full page picture of the present engineering situation, and

in spite of the fact that reams of newspaper propaganda has shown up, there is still a feeling that things are not quite as represented. The reversal was so complete that the present facts cannot be whole-heartedly accepted. Some of the reports of over-supply which cropped up last year had their beginning in the policies and fears of engineering educators a few years ago. Such a feeling was communicated to several Cleveland school officials as far back as 1946. In the same vein they look askance at the enlisting of girls for the engineering profession feeling that there is too much danger for such action to end up as pure exploitation. To reverse this opinion the Counsel and enthusiasm of successful female engineers must be evident.

Influence of Technical Councils

Another factor entering into the Cleveland situation is its relationship with the Cleveland Technical Societies Council. This Council has been very active in the conduct of career conferences on engineering. Some 40 members of these different Societies helped conduct this year's conferences, one of which was held on the east and the other on the west side of the city. In spite of all their efforts and hard work the value of the conference seems to be diminishing and the success of this year's affairs might be seriously questioned. High School Sophomores, Juniors and Seniors are permitted to attend. In these three classes within the city of Cleveland there are probably some 6000 young men, 2000 of them in the Senior level. A total of 364 of these young men attended the two conferences. A talk was given by one of Cleveland's engineers and was well received by the students present. A series of nine panel discussions were organized to follow the address. A movie was inserted into the program which brought the actual beginning of the individual panel discussions to a point well after 9 P.M. at which time several of the students left for home. The movie, itself, was well made, but we doubt if it could be called psychologically correct for the inspiration of young minds as it made little attempt to tie the student's present experiences into the potential abilities which he might possess. Most of the examples given were too far beyond the scope of the high school mind.

The junior and senior high school students, according to Cleveland Educators, have committed themselves to a course of study. If they have failed to take basic engineering college requirements it is too late, in most cases, for correction. As tough and unreasonable as it seems, under our present engineering college curriculum and requisite admissions procedures, a high school student must make up his mind as to general classification of life work *while still in Junior High School.* Efforts to interest young minds must be directed to and adjusted for that age group.

There is serious question in the Cleveland School System as to the worth-whileness of continuing this conference. If it is to be continued, then greater inspiration, more skillful handling of invitations and the meetings themselves and more effective dramatization of the careers in engineering will be required.

Progress and Problems

During the past few years, engineering has taken on a broader connotation as evidenced by the efforts to inject business and social understanding into the curriculum. Engineering education is preparation for a way of life, just as the study of medicine, of science and of the clergy are ways of life.

Engineering has had a very human function during its existence. The engineer has devoted his every attention to making slaves out of machines and things instead of people. It is the engineer who has lifted humans from slave conditions toward the American ideal of individual human dignity. Our national strength and well-being has grown in proportion to the growth of engineering education. The engineer of the past century has done

more to accomplish the dreams of the world's philosophers than all of the literature and lip service of 20 centuries. Engineering is a worth while kind of life.

This concept, and the present shortage of candidates requires some compromise of past standards and ideals. We must first acknowledge and be sensitive to the problems of the secondary school educator and then proceed to find ways of cooperating whole-heartedly with them. The ultimate people we must influence go beyond those with whom we have been dealing up to the present. In trying to expand the entering Freshman engineering class we are reaching into a different type of family and to a different type of student.

It has been a varying policy in engineering schools to look somewhere in the upper 20% of the graduating classes for prospective engineering students. We are reaching below this now and it is very possible that in the next four or five years you will have to reach way down to graduate 30,000 engineers a year. You may even get down to the average American family where the income as a unit is in the neighborhood of $3500.00 and papa has an average educational attainment of one year in high school. In reaching for talent down to this level we can expect other human problems to enter into the scene which we will not discuss in this paper.

Some Engineering Advantages

The engineering profession has much to sell. There is the essentially very human and established fact that the engineer is a better husband and family man and a good though quiet citizen in his community. We have heard Engineering Deans state that some 43% of the men entering the engineering profession develop into executives and company presidents. There must be some qualities which engineering studies impart or such a large number would not be promoted to positions of executive responsibility. Perhaps this study develops a disciplined mind and at the same time creates a relatively more honest individual.

The engineer, by reason of his ability to organize and direct activity, as well as by reason of his engineering knowledge, has a more flexible earning power than is the case with many an individual. His feeling of personal worth is perhaps as high as that of the medical profession and most certainly there are none higher. There is a patriotic appeal at the moment because it must be acknowledged that we cannot match man for man with the rest of the World but we certainly can match intelligence if we organize ourselves to keep the pipe lines which educate this intelligence sufficiently filled.

Suggestions

We were really pleased to learn recently of the certificates which Purdue University issues to every student who must leave school before graduation for one reason or another. It acknowledges that he has had some engineering study. Much more could be made of this one basic fact and perhaps a slight rearrangement of curriculum in most colleges would make one year of engineering study a definite value, and two years would give a very firm foundation. This will enable a young man to continue through self-study and night school his personal development at a pace which would not normally be possible without this basic training. Cleveland educators suggest that some designation such as "Junior Engineer" might be applied to young men finishing a two year program so as to give more standing to those who cannot afford or cannot master the full curriculum. To many, this point is one which has been neglected by the engineering profession and one which should be capitalized upon as it would help many young men prepare for a better life.

The Counselors and high school educator can be influenced from the industrial angle through employment on special projects or during the summer vacation months. Other efforts to recognize the contribution of these people in the development of young men and the ultimate stature of our Nation could be explored

by Professional Public Relations personnel. Anything at all that would help establish the personal worth of the high school educator and beyond that those things which would permit engineering colleges to acknowledge and honor this worth would help ease and ultimately develop fullest cooperation.

The publicity, the booklets, the movies and every other tool which the engineering profession uses to build up the proper student body will all be helpful. We should not forget, however, that the greatest sales argument in the world is to have someone else attest to the value of your product. The young engineer and *enthusiastic* (an important factor) engineer in industry is the greatest argument for engineering study. To these engineers as individuals we must look for assistance in making the final decision in the mind of the high school graduate and his family. It will be his influence and his persuasion of this student and his parents and upon secondary school educators that will be the greatest single force in helping us to realize our self-set goals. It is this group that must be organized and guided so that their efforts will be adept and meaningful where it counts.

College Notes

The appointment of Malcolm S. McIlroy as assistant director of the School of Electrical Engineering at **Cornell University** was announced. Professor McIlroy, who has been a member of the Cornell faculty since 1947, was awarded the John M. Goodell Prize of the American Water Works Association last year for his work in developing an electrical apparatus to study pressure flows in pipeline networks.

An important new research program designed to provide information which will enable manufacturers to make the automobile a less lethal form of transportation was announced by **Cornell University.** Springing from Cornell's long-established program in air-safety research, the undertaking will strive for improved automobile design to give the rider greatly improved chances of emerging from accidents without disfiguring, disabling, or dangerous injuries. The Cornell Committee for Air Safety Research, which heretofore has confined its interests to air safety, will broaden its activities and change its title to "The Cornell Committee for Transportation Safety Research."

Questions Concerning the Engineering Curriculum

By L. E. GRINTER

Vice President for Instructional Activities, ASEE
Research Professor, Illinois Institute of Technology

In an article published in the JOURNAL OF ENGINEERING EDUCATION for September, 1951, President Hollister has asked many questions that engineering teachers and administrators must answer if progress is not to be denied. The central question is "how is it possible to meet the needs of the world shaking technology of today by use of a curriculum that has changed only in its details but not in its concept for forty years?" President Hollister has used the word curriculum despite the fact that many college catalogues list a dozen or more engineering curricula. One is justified in this choice of wording because such curricula are nearly all designed to achieve the same objectives.

The following list of objectives inherent in single curriculum building raise the question of realism in regard to our present approach to this problem. Our students must be broadly educated; this should invite study of the humanities, political science and world economics. They must have a background of physical science of a more detailed nature than we consider necessary for a major in any other field except for those who would become physicists or chemists. The same may be said for mathematics. At the beginning level engineers must give time, we believe, to drawing and descriptive geometry and later to surveying or process work from which all other students are free. Then they must develop a command of several of the applied sciences of engineering. Eventually they must achieve capacity to design which is the heart of engineering curriculum building. Believing as we do that only economic design is good design we also emphasize costs to a greater extent than any other college except the College of Business. To prepare our graduates to take their places in supervision or administration, which is the destiny of a majority, we accept the necessity for study of personnel relations, business organization, and management. Now add to these objectives the need of every engineer for breadth of knowledge in several fields of engineering and the importance of the mental discipline that only comes from specialization. Is it necessary to continue further or has the elastic limit already been exceeded? Can all of these objectives be achieved to a useful level for most students in four-year curricula?

If your observation of our product leads you to question the success of making the engineering curriculum try to meet so many objectives in so limited a time, what are the alternatives? I suppose they are first *to use more time* or second *to reduce the objectives per student*. If nearly all of our students were destined to spend a lifetime working as engineers, no doubt we would long since have extended the period of training to five or six years. But we know that large numbers study engineering without strong professional objectives. Also, there is no obvious alternative study for many young men who desire to live and who know that

they must make a living within the broad framework of technology. For these students the present curriculum is sufficiently long and perhaps too specialized. But for those whose interests are in professional specialization the curriculum offers insufficient opportunity to lay a firm foundation in basic science, in mathematics, and in the engineering sciences that support specialization.

If we accept these observations as sufficiently true to rule out drastic solutions, such as longer programs for all students, what opportunities remain for facing the questions raised by President Hollister? Must all students be treated essentially alike? Is it reasonable to place those who desire to become professional engineers and those who wish merely to study engineering under restrictions of the same curriculum for four years? Despite great differences in aptitudes should all electrical engineers, for example, receive the same preparation for design? Is it even necessary that all should have the same humanistic background, or might some be allowed to emphasize non-technical studies as background for engineering statesmanship while others might choose the limited objective of becoming a good designer? Perhaps an even more restricted objective would serve for some students while breadth of education would best meet the interests of others.

It seems to the writer that the emphasis upon the multiple branches of engineering in curriculum building may have passed its zenith. Certain needs and opportunities that are becoming more clear are forcing the branches of engineering education to draw closer together again. Research and its special needs is one such influence. Administration is another. Perhaps our interest in developing spokesmen or statesmen for the profession is a third. The question to be raised is whether we can provide the flexibility within individual curricula to take care of the diverse interests of designers, researchers, managers, constructors, salesmen and statesmen? If our answer is yes, we must start to question the concept of a fixed curriculum pattern for all engineers even within a single department of a single institution. Certainly we should then encourage the greatest reasonable divergence between programs in different institutions.

ANNUAL MEETING

June 23–27, 1952

Dartmouth College **Hanover, N.H.**

Engineering Research in the Program of the National Science Foundation *

By DR. PAUL E. KLOPSTEG **

Assistant Director for the Mathematical, Physical, and Engineering Sciences of the National Science Foundation

As representative of one of the university members of the Engineering College Research Council for a number of years, it is pleasant to renew associations with this group. Having only recently assumed responsibility for direction of the Mathematical, Physical, and Engineering Sciences Division of the National Science Foundation, I am sure that my profit in getting your views and comments will be greater than yours in listening to this speech. I am grateful for the opportunity to meet with you.

Engineering has been characterized as the art of directing knowledge of the physical sciences towards useful ends. Another summary statement, attributed to the distinguished engineer, Gano Dunn, is: "Engineering is the art of the economic application of science to social purposes." Still another, inscribed on a wall of the headquarters building of the Engineering Societies is: "Engineering is the art of directing men and controlling the forces and materials of nature for the benefit of the human race."

All three of these statements assert, in common, that engineering is an art, namely, the art of directing, applying or controlling something, for the benefit of mankind. Although each differs in form from the others, all express essentially the same thoughts, and we may, I believe, accept them as a fair characterization of our field.

Functions Prescribed by the Act

The National Science Foundation Act of 1950, which established the Foundation as an independent agency in the executive branch of the government, authorizes and directs the Foundation to perform certain functions. Those of particular interest to engineers are:

(1) To develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences; (2) to initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering and other sciences . . . (4) to award scholarships and graduate fellowships in the mathematical, physical, medical, biological, engineering and other sciences; . . . (6) to evaluate scientific research programs undertaken by agencies of the federal government, and to correlate the Foundation's scientific research programs with those undertaken by individuals and by public and private research groups.

These functions, quoted from the Act, contain two points that are worthy of special attention: First, it is unequivocally stated that the Foundation shall concern itself with *basic scientific research;* second, engineering is regarded not as an art but as a science. It is, in fact, called a science. Further along, the Act specifies that there

* Presented before the Engineering College Research Council at the Fall Meeting of the ASEE, Houston, Texas, November 15, 1951.

** On leave from Northwestern Technological Institute.

shall be initially four divisions (with the provision that others may be established by the National Science Board) of which the second is called "Division of Mathematical, Physical, and Engineering Sciences."

Perhaps the extent of the incongruity is not so great as might appear at first sight. As used in the definition of engineering, "art" clearly means skill; and to become skillful in applying the principles of the physical sciences to human needs and desires requires further knowledge that must be acquired through research. Implicit in the concept of engineering, moreover, is the social aspect; there is no engineering unless it be directed towards ends that are useful and desirable to human beings. Science, on the other hand, is completely impersonal in its aims and ideals.

Basic Research vs Applied Science

Ideally, the scientist has but one aim: to penetrate and conquer the areas of ignorance and annex the territory thus gained to the contiguous areas of knowledge. Perhaps this description may serve as a working definition for basic research; perhaps also it may help our thinking about basic research in engineering. If penetration and conquest of ignorance is an essential step in research, engineering may lay equal claim, with science, to the procedure; for science has no monopoly of that which is unknown. It seems quite unprofitable to try to write specifications for ignorance, or to subdivide it into areas. The point of this discussion is that lack of knowledge about applications of scientific principles to a particular situation is ignorance just as truly as is lack of knowledge of the principles to be applied. Hence it seems logical to take the position that research directed towards methods and procedures of applying knowledge towards useful ends is research as truly as that which seeks knowledge of science in the first instance. I am mindful, furthermore, that in seeking to devise the procedures and methods of application, engineering research must always be concerned with the economic and social aspects of its possible results. This makes the research no less basic.

There is another approach to the problem of what constitutes basic research, in general, and basic research in engineering, in particular. In the sciences, it seems generally accepted that basic research has as its sole motive the search for new knowledge. The scientist engaged in it is free to follow his intellectual nose. His procedure is one of pure inquiry, without external program or direction. From his point of view, anything that savors of the practical, or of applications, is not research, but development. He may yield sufficiently to say that it is "applied" research.

To explore this line of thought in the direction of our thinking will require traversing ground which undoubtedly is familiar to all of us.

We begin with agreement with the scientist as to what constitutes basic research in his field, and recognize that the outcome of his efforts is an addition to knowledge and understanding of some physical phenomenon. Whether this knowledge is usable or useful is at the moment unknown. It is possible, and it frequently happens, that in the course of his investigations some evidence of utility appears; indeed, there may emerge from his activity something that has obvious applicability, with economic or social implications. An example is the Steenbock research on the effects of irradiation, by a certain region in the ultraviolet, of certain steroids, producing vitamin D.

Ordinarily the evidence of utility is not so clear. In most cases, the undertaking by which useful applications of principles are found is initiated as the result of some economic or social motivation, for finding, devising, or improving procedures, devices or processes in some well defined area. Those engaged in the work thus formulated may be engineers, or they may be working in the vanguard of engineering, in applied science. For them and from their point of view, their work is basic

research. After they have found out how to apply a new principle, and have demonstrated the feasibility of what they have found, the project enters the engineer's domain. I hasten to say that there is no clearly-defined boundary; the scientist may have to do some engineering, the engineer may have to make an occasional journey into science.

Broadly speaking, of course, engineering is applied science; but in this discussion I conceive of it as applied science plus something more. That something more is a thorough awareness of the economic and perhaps, in some measure, of the social aspects of the general problem. He takes over, and carries the design, or method, or process forward to its economic utilization, including the important functions of initiation, supervision and control of the steps involved by which the product is put in final form for use by the public.

There is another possible avenue of approach to testing whether a given research activity is basic. This is the question of the motive of the research worker. It is held by some that unless the motive is solely to add to knowledge without concern for any other considerations, the research is not basic. Under this conception, it is possible that two people might begin with identical knowledge and arrive at identical results, each under the stimulation of different motives. One of them has no practical objectives in mind. The other has. On the basis of such a test, then, the research would be basic for Worker A but it would not be basic for Worker B. I cite such a possibility only because it illustrates the difficulty of appraising proposals. For some purposes the test of motive might be entirely proper and practicable, but it would seem a little difficult to employ this test in appraising suggestions or proposals to the Foundation.

Each Proposal on its Own Merits

From considerations such as these one may derive some of the intellectual satisfaction that comes from the arrangement of ideas in a logical pattern. Actually, in carrying on the work of the National Science Foundation, we cannot—desirable as they may be—write any rules or devise any standards of measurement that could be applied to a particular proposal to determine whether the project in question is or is not in the category of basic research. It is obvious, in view of our having to deal so extensively with opinion, that no simple criterion, capable of being mechanized, or of being developed into simple routine, can be established, against which to appraise a proposal. That which is basic research to an engineer will in all probability not be so regarded by the scientist, either in the applied field or the fundamental disciplines. Each situation will have to be evaluated with the best judgment that can be brought to bear upon it, and decisions reached in harmony with the broad objectives of the Foundation.

The National Science Foundation is trying to develop its organization and procedure in such a way that only thoroughly qualified persons will be considering proposals for research in any area of science and engineering. Moreover, it is the intent of the National Science Board that basic research in engineering will be supported, whether or not the subjects to be investigated bear the specific label "engineering." We have, for purposes of aiding our own thinking, prepared lists of many such subjects, and members of the Board have found these to be appropriate illustrations of research in engineering. Here are a few samples, illustrative only, and by no means inclusive:

Transient flow in porous media.

Fatigue characteristics of engineering materials under conditions of variable cycle loading.

Fluid friction in unsteady motion.

Surface temperatures of sliding surfaces.

Theoretical study of detached shock waves.

Study of the earth as a thermal source and sink.

Solar energy studies.

Diffusion in liquids near the critical point.

Influence of ultrasonics and microwaves on chemical reaction rates.

Theoretical studies of interaction phenomena of electric charges and electromagnetic fields.

Properties of wave guides, wave guide filters.

Power measurement at radio and microwave frequencies.

New methods of performing mathematical operations with electronic computers.

Intermetallic compounds as high temperature materials.

Correlation of crystal structure of refractories with thermal shock properties.

Correlation of dielectric properties of mica with crystal structure.

Plastic flow and stresses within the grains of metals.

Oxidation of metals at high temperatures and pressures.

Application of measurement and control to research problems in various sciences.

Methods of Financing Research

The National Science Foundation Act provides a large degree of freedom in the choice of means for supporting research. For the most part, such support will be given through financial assistance to organizations and individuals primarily for the conduct of research. In connection with such work there may be necessary field trips or expeditions, development or purchase of instruments or other equipment, and the construction, modification or purchase of laboratories or other facilities.

Direct support of research is, however, not the only function of the National Science Foundation, as is evident from the recital of functions which were quoted earlier from the Act. Accordingly, it is also anticipated that support will be given for education and training of scientific personnel, through the Division of Scientific Personnel and Education, largely by a program of fellowships and, later, of scholarships. Other activities are contemplated, all of which bear directly or indirectly on research in the natural sciences.

Heretofore two methods have been widely used by government agencies for financing research. One of these with which I am sure all of you are familiar is the contract. The basis of a contract is a quid pro quo, that is, the exchange of specified performances. One form of the contract has been the fixed price or lump sum contract under which, when used in research, the contractor agrees to specific performance in return for an agreed upon compensation. This requires that the cost of the work to be done be estimated in advance in fairly specific terms. In basic research it is difficult, if not impossible, to make such accurate determinations. The administrative advantage in the fixed price contract is the absence of a need for supervision of actual costs incurred. The lump sum contract has been used principally by the National Advisory Committee for Aeronautics and the Atomic Energy Commission.

The better known kind of contract used by government agencies in recent years is the cost-reimbursement contract. This type of contract, covering research and development, was first widely used by the OSRD during the war and more recently by ONR and others. It provides for compensation for all costs incurred in the accomplishment of the work. The difficulty of defining costs and of determining what costs have been incurred is probably well known to all of you. Efforts to meet the difficulties have been evolved through a wide variety of specialized forms within the general framework of this type of contract.

Such a contract almost invariably requires elaborate financial and property accounting systems and audits. All of this may prove burdensome, especially in contracts that do not involve large

amounts. They also result in relatively large costs of administration both for the government and the contractor.

Inasmuch as the Foundation is specifically authorized to make grants for the support of basic research, it is now anticipated that this form of support will be most generally used by the Foundation. In the practice of both private and government institutions, a grant is a donation of money, property or other valuable thing usually for the accomplishment of an agreed-upon purpose. Like the contract, the grant takes different forms depending upon the purpose to be achieved and the relationships established between the parties. Typically, the grant is characterized by statements of objectives and essential undertakings. It does not require detailed financial and administrative arrangements. Payments to the grantee are usually made in advance either in total sum or relatively large installments. Reliance is placed on informal understandings rather than legal safeguards although legal protection against deception and noncompliance is preserved. Compliance is achieved principally through continuing relationships between grantor and grantee.

As you are aware, the grant for research has been most widely and almost exclusively used by private foundations.

For many reasons, the grant seems particularly appropriate for the support of basic research by the Foundation. It is anticipated that most projects that will be supported by the Foundation will arise through the initiative of individuals of demonstrated competence who have a keen interest in exploring some particular area and who lack the means necessary to carry on the work with expectation or hope of reasonably early results.

Proposals are now being received by the Foundation. As it becomes more widely known that funds are now available for operation, it is expected that proposals will appear in increasing numbers.

It is necessary at this point to inject a word of caution. Proposals should "come from within," that is to say, from people who have a compelling urge to do basic research in the fields of their specialty. Proposals should not be "dreamed up" for the sake of obtaining a grant. It is the duty of the Foundation to examine not only the subject matter but also the ability of the proposer and the facilities at his command.

Although no special form is required, the staff of the Foundation is preparing a set of suggestions which proposers may follow in seeking a grant. Very briefly, it will be desirable to include in an estimate the following items:

a. Individual salaries of both full- and part-time personnel.

b. Cost of capital equipment.

c. Cost of expendable equipment.

d. Other direct costs such as travel and publication costs.

e. Indirect costs (up to 15 per cent of total direct costs).

Several of these items will raise questions, some of which are difficult or, at the moment, impossible to answer. For example, the publication of results of research is a matter of expense which some government agencies are not permitted to reimburse. On the other hand, the position may logically be taken in matters of basic research that the research has not been completed until its results have been made widely known to others working in the same field.

Overhead Allowances

Another question which I am sure would be asked, if I did not mention it, is the question of indirect costs, sometimes known as overhead or in business as "burden." No doubt many of you have spent many hours discussing this question with representatives of government agencies in connection with the cost-reimbursement type of contract.

In grants made by the Public Health Service and in many of the lump sum contracts of the Atomic Energy Commission, 8 per cent of total direct costs has been used as compared with various percentages ranging between 5 per cent and 100

per cent or more of the direct payroll in the cost-reimbursement type of contract.

In arriving at a suggested figure of 15 per cent of total costs, several ideas have come into the picture. One of them is that the capital equipment employed in the research will in most cases become the property of the institution or organization receiving the grant. Another consideration is the fact disclosed in a survey that 15 per cent of total direct cost may amount to somewhere between 20 and 30 per cent of payroll. Moreover, since we are considering only basic research, namely, the type of research which universities generally consider as part of their normal activity, it may be assumed that they may not be averse to participation to a limited extent, this extent being the difference between the actual indirect costs, assuming these to be known, and those provided for by the 15 per cent of the total. Since there is no provision either for an audit or for advance determination of actual indirect costs, there will be no occasion to discuss the question once a university or other institution has agreed to accept the grant on the basis suggested. Perhaps it is not out of place to mention at this point that grants from private foundations do not provide for indirect costs.

Another important consideration is that with possible rare exceptions, all results of research done under a National Science grant will be unclassified. There will be freedom of publication—a most desirable sequel to a project from the standpoint of the university and an essential one from the standpoint of the scientific community. The value of publication to the investigator and the university is obvious; it is the reward for work well done and for an enlightened institutional policy. Through it the individual and his university gain stature and prestige, and through it they achieve the satisfaction of having added to our knowledge.

Possibly the most cogent point is that in the National Science Foundation something new is added to American science, namely, an opportunity—at the moment a sharply limited opportunity because of a severely restricted budget—for those who have the ability and the desire to do basic research to obtain adequate funds to carry on this work, thus enabling their institutions to meet an obligation and a function that they have long recognized but which they have been unable to fulfill for financial reasons.

Other Considerations

Other questions to which the answers may to some extent be anticipated will arise. The following answers are tentatively given and I say tentative because experience may show the need or desirability for change.

The typical grant instrument will be exceedingly simple. Under it the research worker will not be required to be a bookkeeper or accountant. He will agree to carry on his research under a statement of aim and scope of the work. His performance will be largely the result of his ability and integrity in carrying out his intentions.

The funds allocated by the Foundation for research usually will cover more than a government fiscal year. They will, probably after the present fiscal year, run for several years, and may run as long as five years. Most of you already know that the President's request for an appropriation for the Foundation for the fiscal year 1952 was about $14,000,000, that the House of Representatives cut this to $300,000, that the Senate brought the amount back to $6,300,000, and that the final figure agreed upon in the conference committee was $3,500,000. The point of this comment is that we cannot be complacent and think that because we now have a law, the purpose of which is to initiate and support basic scientific research and other related matters, scientific research is now provided for and can move forward as quickly as the ability and availability of scientists make possible. This is by no means the case. It is quite evident that notwithstanding the four or

five years during which science legislation was in process, there is still insufficient appreciation of the meaning of basic research among the public at large. All of us who are interested in seeing the objectives of the Act realized must continue to work towards the end that from these beginnings an effective organization may develop. The Foundation is definitely in its infancy and a good deal of intelligent care is needed to assure its normal growth. Our task has only begun.

In view of the fact that we are dealing with basic research, it is not anticipated that many inventions will be made. In the event that there is invention, the instrument of the grant will permit the grantee to file for a patent at his discretion with the sole requirement that the Foundation be notified and in case the patent goes to issue, the government shall have a royalty-free license or so-called shop rights.

It is expected that when a grant has been made, the grantee will make an informal report or a series of reports to keep the Foundation informed of the progress of the work.

In a discussion such as this, it is obviously impossible to cover all details. The most important matters pertaining to the administration of the support of research have been presented.

To carry out the support of research and other objectives recited in the Act, an organization is gradually being developed. In the Division of Mathematical, Physical, and Engineering Sciences there is as yet no staff, but we are seeking qualified scientific personnel to head the several sections which will be concerned with the various physical sciences. The eventual size of the staff cannot at the moment be predicted. Under this year's appropriation, we shall have to move with caution.

It is my hope that in this presentation I have not given the impression that we in the Foundation know all the answers or even a substantial fraction of them. As I see it, the National Science Foundation is in something of an experimental stage. It is a great opportunity for the scientists of the country, provided they have the wisdom and whatever other qualities are needed for making scientific research flourish and produce results on a scale never before possible. These results, if the objectives of the Foundation are achieved, namely, the objectives envisaged in the Bush report entitled *Science, The Endless Frontier* and in the Steelman Report, *Science and Public Policy*, will then truly become the firm basis for the further progress not only of our own country but of all mankind on a scale which can be limited only by the imagination, and by the ability and effort that we put into this work.

Mid-Winter Meetings

A conference of the Division of Relations With Industry will be held at the Massachusetts Institute of Technology on February 2, 1952. The theme of the conference will be "The Student as an Individual." A meeting of the Advisory Committee of the Division will be held on Friday, February 1, 1952, at 9:30 A.M. The first draft of the papers to be presented at the June meeting will be discussed.

The Mid-Winter meeting of the Engineering Drawing Division will be held at three New York universities—The Cooper Union, U. S. Military Academy at West Point, and Columbia University on January 23, 24 and 25, 1952. The complete program was published in the November issue of the JOURNAL OF ENGINEERING EDUCATION.

Summary of Resources for University Research

By A. F. SPILHAUS

Dean, Institute of Technology, University of Minnesota

and

JOHN I. MATTILL

Secretary, Engineering College Research Council

The importance of making full and effective use of all of America's power for scientific research and development is manifest today. Urgent requirements for national defense have been superimposed on the growing needs of industry for all kinds of scientific research—both at a time of decreasing scientific manpower supplies. For the first time in its history, the nation's collective budgets for research and development in the physical and engineering sciences are seriously limited not by available funds but by available research capacity.

Already the $1.1 billion military research budget requires 56,000 research scientists and engineers, or 43% of the total available in the United States. In 1952, with the desired expansions and including studies sponsored by the Atomic Energy Commission and other agencies engaged in defense research, military research will require 65% of this manpower supply. Before the outbreak of hostilities in Korea, the nation's annual research and development expenditures were $500 million. By 1952 they must be expanded nearly three-fold, to $1.3 billion. Colleges and universities are responsible for 9% of the present research and development total; they must have at least this same share in the vastly larger 1952 total.[1]

[1] "Research and Development: The Nation's Balance Sheet in June, 1951," by Dr. Eric A. Walker, JOURNAL OF ENGINEERING EDUCATION, Vol. 42, No. 3, pp. 126–133 (November, 1951).

American colleges and universities include within their staffs and faculties an important segment of the nation's scientific manpower—at present about 20% of the 120,000 people now in research in the United States. Fully effective use of college and university potential may considerably raise the ceiling placed on research and development progress.

Early in November, 1950, the Research and Development Board in the Office of the Secretary of Defense reported to the Engineering College Research Council's Committee on Relations with Military Research Agencies its concern with this problem.[2] The Board told the group that the research responsibilities of colleges and universities can be efficiently increased only if the nature and extent of educational institutions' research re-

[2] The members of this Committee include Dean A. F. Spilhaus, University of Minnesota, Chairman; Dr. A. P. Colburn, University of Delaware; Dean W. L. Everitt, University of Illinois; Professor F. B. Farquharson, University of Washington; Professor C. W. Good, University of Michigan; Dr. Paul E. Klopsteg, Northwestern University; Dr. James S. Owens, the Ohio State University; President J. R. Van Pelt, Montana School of Mines; and Dr. Eric A. Walker, the Pennsylvania State College. The survey described on the following pages was carried out from headquarters in the office of the Secretary of the Engineering College Research Council, John I. Mattill, Massachusetts Institute of Technology, with the assistance of Miss Jean P. Stevenson.

sources are clearly established. This pointed clearly to the need for a national inventory of the abilities, interests, and qualifications of educational institutions to undertake research in the physical and engineering sciences.[3]

The Committee noted that such a study, if it could lead to more efficient utilization of these resources, would not only be of importance in the national interest —but would as well have great significance for scientific education. Opportunities to undertake research for national defense may be valuable to colleges and their faculties in a time of reduced teaching loads and increased financial problems. Research, under any circumstances, can make a most effective contribution to an educational program, and the potential importance of this factor is heightened by today's desperate need for well-equipped young scientists and engineers.

The inventory, as finally outlined by the Committee, concerned itself with three general subjects:

1. The number of scientists and engineers available at educational institutions.
2. The particular areas within their professions in which these persons are especially qualified to undertake research, by virtue of professional interests or teaching or research experience.
3. Those unusual facilities for scientific and engineering research which especially qualify an institution for research in a particular problem or area.

To obtain data for this national inventory, the Committee developed a special questionnaire form, designed to be as simple as possible within the limitations of the information needed and to produce answers suitable for mechanical processing and comparison. The most difficult task in formulating the questionnaire was to provide a checklist of research interests and specialties within the broad professional and scientific fields. In final form this checklist consisted of a new combination of features from a number of breakdowns, including forms used by the Human Resources Section of the Research and Development Board, based in turn on older material used in compilations for "American Men of Science," and on the classifications adopted by the Engineering Index.

The Committee was aware of the many shortcomings of the questionnaire process, but no adequate alternative seemed possible to meet the pressing time schedule recommended by the Research and Development Board. Obviously, replies from colleges in their own words emphasizing individual problems and suggestions would provide more worthwhile data than the cold statistical process adopted. But the Committee was unanimous in agreeing that such a desirable procedure was not practical.

The questionnaire form finally adopted was mailed early in February, 1951, to 990 colleges and universities throughout the United States, including all four-year educational institutions presumably offering courses in scientific or engineering fields (as listed in the Higher Education Section of the *Education Directory,* published by the U. S. Office of Education). By May 1, when the inventory was declared completed, replies from 747 educational institutions were on file. Of these, 525 reported personnel available for research in one or more of the physical or engineering sciences. An informal review of the list of institutions from which no inventory or acknowledgment was received suggests to the Committee that substantially all of the national potential for research in the areas covered by this project is reported.

1. Personnel

To determine the numbers of scientists and engineers in colleges and universities —and particularly those available to increase the nation's research and develop-

[3] The critical field of Psychology and Human Resources was added at the suggestion of the Research and Development Board, since data of this nature was urgently needed for that area.

TABLE I

SUMMARY OF PERSONNEL REPORTED IN SCIENTIFIC AND ENGINEERING FIELDS

	Total Number of Faculty and Full-time Research Personnel *A*	Number of (*A*) Considered Qualified to do Research *B*	Number of (*A*) now Engaged in Research *C*	Number of Full-time Research Workers to which (*C*) is Equivalent *D*	Number of Research Workers in (*D*) now Engaged in Research for National Defense *E*	Number of Graduate Students and Assistants now Engaged in Research *F*	Number of Full-time Research Workers to which (*F*) is Equivalent *G*
Aeronautical Engineering	652	597	437	289.7	236.8	566	284.2
Astronomy	279.3	246.8	159.8	105.3	39.5	225	130.1
Ceramics	216	200	156	108.8	42	215	122
Chemical Engineering	735.5	701.5	564	279.8	99.4	1,699	807.4
Chemistry	3,711	3,319.5	2,435.7	1,316.1	506.2	6,949	3,468.4
Civil and Sanitary Engineering	1,698	1,429	654	313.6	112.1	936	443.1
Earth Sciences	1,447.8	1,322	964.2	452.4	172	2,086	861.5
Electrical Engineering	1,497	1,237.5	601.5	288.1	219.1	1,125	456.5
Electronics	1,119.4	1,032	625.6	387.2	313.8	1,107	557.8
Food Technology	755.2	634	420	272.6	52.6	692	346.7
Industrial Engineering	535.5	421	173.5	77.1	14.1	352	108.9
Marine Engineering	78	71	35	17.7	12.5	24.2	13.9
Mathematics	3,297.3	2,261.8	1,167.3	570	209.3	1,496	640.7
Mechanical Engineering	2,002.5	1,660.5	716	327.1	150.5	1,119.5	434.5
Mechanics	963.7	820.5	424.7	213.3	119.3	557.2	244.6
Metallurgical Engineering	487.5	458.5	349.2	187.6	131.7	757	387.7
Mining Engineering	135.5	128.5	82	44.4	11	129	50
Petroleum and Fuels Engineering	209	195	112	72.7	12.5	197.2	81.7
Physics	2,628.4	2,271.9	1,546	866.6	609.3	3,392	1,562.1
Psychology and Human Resources	2,432.4	2,029.2	1,242	554.7	227.1	3,161.5	1,141
Totals	24,881	21,037.2	12,865.5	6,744.8	3,290.8	24,785.6	12,142.8

ment activities by undertaking new responsibilities at their own institutions—the Committee asked each institution seven questions in each field of science and engineering represented in the inventory:

A. How many faculty members and full-time research personnel of equivalent rank are now active?

B. How many of these are considered qualified to participate in research projects?

C. Of these, how many are now active, full- or part-time, in research?

D. To the work of how many full-time research workers (35–40 hours per week) is this activity equivalent?

E. Of this "equivalent number" of research workers, how many are now engaged in research for national defense?

F. How many instructors, graduate students, and teaching and research assistants are engaged full- or part-time in the department or field?

G. To the work of how many full-time research workers similarly trained (35–40 hours per week) is this activity equivalent?

The answers to these questions, tabulated in Table I by the various fields of engineering and science covered in the project, provide an inventory of about 25,000 faculty members and senior research workers, and 27,000 graduate students, instructors, and junior research workers. The total of these, 52,000, is a little above but substantially in agreement with the estimate for university scientists in 1951–52 contained in the Steelman report (based on an analysis of the National Roster of Scientific and Specialized Personnel in 1947), allowing for the numbers of scientists and research workers in fields not covered by this questionnaire.[4]

[4] "Manpower for Research," volume IV of *Science and Public Policy*, report by the President's Scientific Research Board, U. S. Government Printing Office, 1947, page 31.

The totals in Table I show that more than 20,000 faculty members are considered by their institutions to be qualified to perform research, but only 12,700 are active in research. Thus 8,000 faculty members considered qualified to perform research are not now doing so.

An average of 27% of the time of the faculty members reported in this inventory is spent on research activities, and 49% of this research time is already devoted to defense research.

Putting these figures in another way: Of the 25,000 faculty members reported, one-half are active in research; these spend about one-half of their time in research, and one-half of this time in turn is devoted to military research. *This means that one-eighth of the total college effort in these fields is devoted to military research.*

This military research activity is the equivalent of the work of a full-time force of 3300 senior research scientists and engineers—a very considerable strength in the service of the nation and a very reassuring evidence of scientific and engineering resources. Yet 8000 more faculty members not now active in research may still add their contribution to this working force. If this can be done, and they become active in research on a quarter-time basis, the equivalent of 2000 more full-time research scientists is added to our research force. Our defense research in colleges and universities could thus be increased by more than 60%, with no decrease from the present level of the non-defense research effort. A quarter-time research assignment presumably does not interfere with teaching responsibilities and, in fact, might greatly improve the professional work of most teachers.

The inventory's statistics show the variations in these relationships between the various physical and engineering sciences represented. Table II shows, for example, that defense demands are now absorbing 82% of college and university research work in aeronautical engineering; yet in Table III are figures showing that only 73% of those faculty members deemed qualified to perform research in this field are now active. Table IV gives confirmation of one characteristic of academic work in various fields which is well known in less quantitative terms: 77%

TABLE II

PERCENTAGE OF SENIOR STAFF RESEARCH TIME DEVOTED TO DEFENSE RESEARCH

Aeronautical Engineering	82%
Electronics	81
Electrical Engineering	76
Marine Engineering	71
Metallurgical Engineering	70
Physics	70
Mechanics	56
Mechanical Engineering	47.5
Psychology and Human Resources	41
Ceramics	39
Chemistry	38
Earth Sciences	38
Astronomy	37
Mathematics	37
Chemical Engineering	36
Civil and Sanitary Engineering	36
Mining Engineering	25
Food Technology	19
Industrial Engineering	18
Petroleum and Fuels Engineering	17

TABLE III

PERCENTAGE OF SENIOR FACULTY CONSIDERED QUALIFIED WHO ARE NOW ENGAGED IN RESEARCH

Chemical Engineering	81%
Ceramics	78
Metallurgical Engineering	76
Aeronautical Engineering	73
Chemistry	73
Earth Sciences	73
Physics	68
Food Technology	66
Astronomy	65
Mining Engineering	64
Psychology and Human Resources	61.5
Electronics	60.5
Petroleum and Fuels Engineering	57.5
Mechanics	52
Mathematics	51.5
Marine Engineering	49
Electrical Engineering	48.5
Civil and Sanitary Engineering	46
Mechanical Engineering	43
Industrial Engineering	41

of chemical engineering teachers are active in research, contrasted to less than 40% in mathematics, mechanical engineering, and civil and sanitary engineering.

A comparison of the senior faculty and graduate student time on research shows that, on an average, each senior member directs the work of two assistants. Apparently one way of increasing the nation's research potential immediately—and more particularly in the future—is to find means of increasing this ratio.

The figures in Table V show the fields of greatest defense research endeavor in colleges and universities. One-fifth of the college research effort is in the field of physics; one-third is in the fields of physics and chemistry; and nearly one-half is in the three areas of physics, chemistry, and electronics. Add to these fields the defense research work in aeronautical and electrical engineering and that in mathematics and the earth sciences, and more than three-fourths of the total defense effort in colleges is represented. Chemical engineering, food technology, ceramics, astronomy, industrial engineering, marine engineering, petroleum and fuels engineering, and mining engineering together account for less than 10%. This is convincing evidence that colleges and universities are maintaining emphasis on the fundamental sciences. The Committee is certain that educational institutions must continue to resist temptations to undertake extensive assignments in applied research and development.

TABLE IV

PERCENTAGE OF SENIOR FACULTY MEMBERS ACTIVE IN RESEARCH

Chemical Engineering	77%
Ceramics	72.3
Metallurgical Engineering	71.5
Aeronautical Engineering	67
Earth Sciences	67
Chemistry	63
Mining Engineering	61
Physics	59
Astronomy	57
Food Technology	55.5
Petroleum and Fuels Engineering	53.5
Electronics	52
Psychology and Human Resources	51
Marine Engineering	45
Mechanics	44
Electrical Engineering	40
Civil and Sanitary Engineering	38
Mechanical Engineering	36
Mathematics	35.5
Industrial Engineering	32

TABLE V

MILITARY RESEARCH IN ENGINEERING AND SCIENCE IN COLLEGES AND UNIVERSITIES

	Total "Equivalent" Full-time Defense Research Workers in Colleges	Per Cent of Total College Defense Research
Physics	609.3	19.85%
Chemistry	506.2	16.6
Electronics	313.8	10.2
Aeronautical Engineering	236.8	7.74
Electrical Engineering	219.1	7.15
Mathematics	209.3	6.82
Earth Sciences	172	5.6
Mechanical Engineering	150.5	4.9
Metallurgical Engineering	131.7	4.3
Mechanics	119.3	3.88
Civil and Sanitary Engineering	112.1	3.66
Chemical Engineering	99.4	3.25
Food Technology	52.6	1.73
Ceramics	42	1.37
Astronomy	39.5	1.27
Industrial Engineering	14.1	.456
Marine Engineering	12.5	.425
Petroleum and Fuels Engineering	12.5	.425
Mining Engineering	11	.36
Totals	3063.7	100

2. Research Specialties

The complete report on University Research Potential shows in detail the specialties within the engineering and physical sciences in which each participating college reported one or more faculty members with interests and qualifications. The number of schools reporting interest and qualification in each of the special research fields is shown in Table VI. The Committee points out that there is no

necessary correlation between the number of schools indicating interest in a specialty and the total number of individuals available for research in that field. Rather, these numbers of schools may be more characteristic of the breakdowns adopted in the questionnaire than of any fundamental character of the demand for research in each specialty.

TABLE VI

NUMBER OF COLLEGES REPORTING INTEREST OR COMPETENCE IN SPECIAL FIELDS

Aeronautical Engineering	
Aerodynamics	89
Aeroelasticity	38
Aeronautical structures	53
Aircraft design	48
Aircraft instruments and flight control	32
Aircraft internal combustion engines	47
Aircraft materials	32
Aircraft navigation	20
Aircraft parts and accessories	20
Aircraft rocket, jet and turbine engines	45
Airport engineering	52
Air transportation	12
Airways and flight patterns	3
Automatic control systems	23
Guided missiles engineering	39
Hypersonic engineering	19
Supersonic engineering	43
Transonic engineering	23
Astronomy	
Astronomical bodies	38
Astrophysics	70
Bolometry	8
Celestial mechanics	39
Celestial navigation	54
Light measuring devices	47
Photographic techniques and equipment	42
Radiometers	8
Solar radiation	25
Spectroscopic instruments	40
Telescopes and optical instruments	46
Ceramics and Glass	
Abrasive materials	12
Cements and lime	24
Cermets	26
Chemical stoneware	12
Domestic and structural whitewares and pottery	25

TABLE VI—*Continued*

Enamels and coatings	29
Glass	27
Heavy clay structural products	24
Industrial whitewares	19
Processing equipment and plant design	9
Raw materials and processing	24
Refractories and high temperature materials	30
Chemical Engineering	
Absorption and adsorption	80
Chemical reactions and equilibria	16
Electrical separation	16
Extraction and solvent recovery	76
Heat transmission	82
High pressure processes and catalysis	56
Mass transfer	73
Materials handling	20
Measurement and control of process variables	58
Mechanical separation	41
Phase change separation	67
Pilot plant construction and operation	79
Sonic and ultrasonic vibrations	21
Chemistry	
Analytical chemistry methods	313
Atomic and nuclear structures	48
Biochemistry	171
Chemical reactions and equilibria	180
Chemical thermodynamics	151
Colloidal chemistry	118
Electrochemistry	130
Inorganic chemistry	246
Kinetics	132
Organic chemistry	385
Physical chemistry	320
Radiochemistry and tracer methods	115
Subjects of specialized research:	
Agricultural chemistry	62
Alkalies	8
Cellulose and wood	38
Chemical warfare	45
Detergents and soap	43
Explosives	46
Fats, oils and waxes	54
Fermentation	31
Fertilizers	32
Forest products	18
Germicides, insecticides and fungus control	53
Heavy chemicals	13
Industrial wastes	92
Paints, varnishes and colors	38

TABLE VI—*Continued*

- Pharmaceutical chemistry 71
- Photochemistry and chemistry of photography 47
- Rubber and related polymers 54
- Synthetic resins, fibers and plastics 60
- Textiles 25
- Water and sanitary chemistry 64

Civil and Sanitary Engineering

- Cartography and photogrammetry 133
- Construction engineering 40
- Highway and traffic engineering 101
- Hydraulic engineering 112
- Hydrographic and reclamation engineering 56
- Materials testing and research 139
- Paving materials engineering 73
- Railway engineering 25
- Sanitary engineering and public health 108
- Snow mechanics and permafrost 25
- Soil mechanics and foundation engineering 125
- Structural analysis and design 147
- Surveying and mapping 124
- Water supply engineering 75

Earth Sciences

- Climatology 120
- Crystallography 84
- Dynamic and physical meteorology 58
- Economic geology 175
- Geochemistry 46
- Geodesy 19
- Geography 31
- Geophysics 67
- Historical geology 157
- Hydrology 68
- Meteorological instruments and measurements 69
- Mineralogy 142
- Oceanography 35
- Petrology 139
- Prospecting and ore analysis 70
- Radar meteorology 12
- Seismology 39
- Structural geology 156
- Surficial geology 130
- Synoptic meteorology 48
- Terrestrial magnetism 27
- Upper atmosphere research 46

Electrical Engineering

- Computing machines 81
- Dielectrics and electrical insulation 51
- Electrical control 116

TABLE VI—*Continued*

- Electrical heating 50
- Electrical machinery and equipment 131
- Electrical power generation 80
- Electrical power transmission and distribution 99
- Facsimile and wirephoto 10
- High voltage research 41
- Illuminating engineering 56
- Magnetic materials and measurements 54
- Network theory 103
- Servomechanisms 101
- Telephone, telegraph, and teletype 33

Electronics

- Antennas and wave propagation 106
- Communication theory 133
- Components 62
- Countermeasures 24
- Electro-acoustics 61
- Electromagnetic waves 86
- Electronic circuits and theory 201
- Electronic computers 54
- Electronic control equipment 125
- Electron theory 108
- Electron tubes 114
- Microwave circuits 101
- Miniature and printed circuits 19
- Navigation aids and direction finding 41
- Radar 97
- Radio communication 147
- Radio interference 57
- Radiosonde 20
- Speech security and scrambling 17
- Television 50

Food Technology

- Bacteriology and microbiology 129
- Environmental food factors 52
- Food canning, packaging and preserving 80
- Food stability and spoilage 60
- Nutrition 120
- Production, storage and handling of raw foods 61

Industrial Engineering

- Fire protection 24
- Manufacturing analysis 73
- Mass production and standardization 59
- Materials handling equipment 56
- Occupational diseases 11
- Plant layout and equipment 100
- Production control 93
- Safety engineering 56
- Training devices 51
- Work simplification 83

TABLE VI—*Continued*

Marine Engineering	
Cargo handling and stowage	8
Marine safety equipment	7
Navigation	11
Ports, harbors and port facilities	28
Ship construction	12
Ship design and structures	16
Ship propulsion	16
Warships	6
Water transportation	9
Mathematics	
Actuarial science	68
Algebras	248
Analysis	257
Calculus of variations	121
Cryptanalysis	23
Differential equations	239
Geometry	209
Nomography	67
Operations research	41
Probability	144
Series	156
Statistics	220
Tensor calculus	34
Mechanical Engineering	
Automotive engineering	75
Gyroscopes and gyroscopic instruments	24
Heating, ventilating and air conditioning	134
Industrial furnaces	22
Internal combustion engines	132
Jet and gas turbine engines	61
Lubrication and friction	62
Machinery and machine design	120
Machine tool engineering	63
Mechanical control systems	37
Mechanical properties of materials	75
Power and steam generation and use	97
Refrigeration	93
Stress analysis and photoelasticity	84
Textile machinery	9
Thermodynamics, heat and heat transfer	128
Tropical and low-temperature testing	23
Mechanics	
Dynamics	134
Dynamics of earth action	25
Elasticity and plasticity	105
Mechanics of fluids	116
Mechanics of vibrations	100
Statics	142
Strength of materials	144

TABLE VI—*Continued*

Theoretical mechanics	95
Theory of limit design	43
Metallurgical Engineering	
Corrosion and erosion	52
High-temperature materials	36
Metallurgical analysis	45
Physical metallurgy:	
Fabrication and finishing	38
Ferrous alloys	75
Foundry	56
Light metals and alloys	64
Metallography	96
Non-ferrous alloys	62
Powder metallurgy	39
Theory of metals	61
Welding	54
Process metallurgy:	
Electrometallurgy	33
Ferrous	33
Hydrometallurgy	24
Non-ferrous chemical	23
Non-ferrous pyro	12
Mining Engineering	
Mine exploration and development:	
Surface	25
Underground	24
Mine operation and engineering	27
Mineral preparation and processing	31
Mine safety and ventilation	20
Non-metallic minerals and quarries	17
Petroleum and Fuels Engineering	
Coal and solid fuels	38
Combustion reactions	41
Fuel processing and utilization	29
Gaseous fuels	36
Liquid fuels	50
Lubricants	36
Oil field management	31
Petroleum by-products and derivatives	29
Petroleum production engineering	33
Petroleum refining	32
Petroleum storage and handling	15
Rocket fuels	18
Synthetic fuels and lubricants	22
Physics	
Ballistics	36
Biophysics	39
Cryogenics	36
Electricity and magnetism	243
Electromagnetic waves	104
Heat and thermodynamics	119
High-energy particles and cosmic rays	70

TABLE VI—*Continued*

Mechanics	119
Molecular and atomic physics	124
Neutron physics	51
Nuclear physics	157
Photography	79
Radiation and optics:	
Infrared methods and applications	63
Physical optics	135
Physiological optics	11
Photoelectric phenomena	82
Spectroscopy	168
Ultraviolet methods and applications	48
Visible radiation	48
Radioactivity and isotopes	117
Solid state physics	75
Sound and acoustics	94
Theoretical physics	143
Ultrasonics	44
Underwater sound	43
X-rays	99
Psychology and Human Resources	
Abnormal psychology	169
Aviation psychology	59
Clinical psychology, guidance and counseling	278
Comparative and animal psychology	99
Development psychology	127
Differential psychology	99
Educational psychology	231
Human engineering	97
Industrial psychology	137
Personnel training	136
Personnel utilization	98
Physiological psychology	99
Psychological warfare	31
Psychometrics	191
Receptive and perceptual processes	115
Social psychology, propaganda and public opinion	174

3. *Facilities*

Though this inventory of research resources included both personnel and facilities, its emphasis was obviously on the number and qualifications of the personnel in colleges and universities. Manpower is clearly the limiting factor in most of today's research and development needs; if manpower is available, necessary equipment to implement research can probably be supplied.

The sole aim of the section of this inventory dealing with equipment was to provide a general impression of facilities at any given institution—an impression possibly useful in evaluating the experience of that institution in scientific research. The Committee also hoped to develop a list of colleges and universities with unusual equipment, sufficiently large and complex so that its availability at a specified school is an important factor in the location of research there. The Committee feels confident that the inventory of equipment and facilities developed as a part of this project will be a useful guide in specific instances; but absence of listed equipment should not be construed as lack of facilities and research experience in a given field. Therefore, the data reported is not the kind from which generalizations can be drawn.

Concentration of Research

The tendency to concentrate responsibility for federal research in a limited number of institutions is a very natural one—but one which has unfortunate implications, of different sorts, both for the schools involved and for those not selected. An appropriate amount of research may be most beneficial to the educational processes in a college or university; but over-emphasis on research may impose responsibilities encroaching on effective teaching.

An analysis of the University Research Potential inventory shows a high concentration of defense research projects in a few educational institutions: fifteen colleges and universities account for one-half of the total faculty time spent throughout the United States on defense research, while these same institutions account for only 20.5% of the faculty and senior research staff members.[5]

[5] Eleven schools account for 50% of the federal research and development expenditures in universities over the past three-year period, and 65 schools account for 90% of the contracts, according to Research and Development Board figures. The difference between these Research and Development Board statistics and those developed in the present inventory apparently derives from

In these 15 "favored" schools, 75% of the faculty are active in research, and 70% of their research time is devoted to defense research. At least 85% of those faculty members considered qualified for research are active in it. *A combination of these figures shows that one-third of the effort in these 15 schools is devoted to defense research, compared to one-eighth in the average of all schools.*

The 510 educational institutions responsible for the other 50% of the defense research time reported in this inventory have nearly 80% of the faculty members and 66% of the graduate students recorded. In these schools, an average of 45% of the faculty members are active in research, but only 38% of their research time is devoted to defense activities. Only 55% of those considered qualified are active in research. *Again to summarize, in the case of this large number of institutions: only one-twelfth of the total faculty effort is in defense research, contrasted to the one-third figure found above for the "big 15."* These results are open to two interpretations: either the great number of educational institutions are not undertaking their proper share of defense research responsibilities, or the larger schools are overemphasizing defense research at the expense of educational activities.

The character of this research concentration is still more clearly shown in an analysis of the research at a group of typical highly-endowed, small liberal arts colleges. In these schools 60% of those considered qualified are active in research, 50% of the total faculty has research underway, but less than 20% of the research time is devoted to defense research. *To summarize again, in this case only one-thirty-second of the total faculty effort is in defense research.* (This figure applies equally well to women's, men's and co-educational colleges in this total group.)

the fact that substantial full-time research staffs involved in large-scale defense research projects are not reflected here.

Conclusions

Modern research and development may make unusual demands on those who undertake it, in terms both of equipment and personnel. The increasing complexity of all scientific research—and of its applications in the military arts—is well known. Yet there remain a large number of defense research needs, even those lying outside the range of fundamental research in its narrowest definition, which can readily be provided in packages suitable for the small college laboratory. It is in such laboratories that the greatest potential for increasing our national research and development effort lies, and the Committee is certain that the increasing demand for federal research must involve a more complete utilization of these units.

Another way in which the tremendous deficit in defense research may be aided, not only immediately but with important implications for the future, is by increasing the ratio of graduate students to full-time senior faculty and staff on research projects in colleges and universities where graduate education is underway. Department of Defense research administrators should recognize and encourage contractually the participation of graduate students in their projects. Such activities are an important continuing source of the senior scientists of the future—and also have an immediate utility in getting the job done now. Shortsighted policies in the calling of young scientists for military service can defeat these vital objectives.

Industrial research needs are also grave today, and many of the implications which this report may have for defense research apply as well to investigations meeting the needs of technical industries.

Copies of the full report on University Research Potential, giving full information on all individual institutions included in this national inventory may be obtained from the Secretary of the Engineering College Research Council at Room 7–204, 77 Massachusetts Avenue, Cambridge 39, Massachusetts, for $1.00 each.

Relations Between Nuclear and Electrical Engineering*

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This might be a rather ill-timed attempt to talk about educational problems in connection with prospects for peace-time applications of nuclear power. However, the government is spending enormous sums of our money in about eight national and industrial laboratories already set up for the systematic development of nuclear power plants, so that it would still seem appropriate to explore the services that electrical engineering can perform, and to evaluate whether we might not render better service by planning curricula in nuclear engineering.

It seems clear that electrical engineers contribute significantly to the progress of the atomic power development. Of the over 4000 engineers associated with the technical research and development phases of the atomic energy program as of June 1950 [1] roughly 900 were electrical engineers, being second only to the chemical engineers, who numbered approximately 1400, or about one-third of the total.

Nuclear Engineering

A seemingly simple definition of nuclear engineering as stated by Mr. Luntz, the editor of *Nucleonics*,[2] is "design, construction, and operation of nuclear reactors." This appears also to be the scope accepted by Dr. L. B. Borst, the chairman of the Reactor Science and Engineering Department of the Brookhaven National Laboratory.[3]

Granted that nuclear reactors could be rather important units in themselves if we were at the point where design, construction and operation were a reasonably frequent requirement, could not any number of analogous kinds of engineering be similarly defined? One could at once think of Water Power Engineering, Railroad Engineering, Draw Bridge Engineering, etc., all of which recognize the distinct phases of design, construction and operation.

Tendencies towards such specialization have frequently existed and have induced attempts to formulate distinct curricula for each one of these and many more kinds of engineering. But, is it desirable, or indeed advisable, to let our engineering curricula degenerate into the training of technicians for a specific and narrow field? Should we not rather consider this specialization as the unavoidable byproduct of acquiring "experience" in a field?

Not long ago, any problem contaminated

* Presented before Section M on Engineering at the Annual Meeting of the American Association for the Advancement of Science, December 26, 1950, Cleveland, Ohio.

[1] Philip N. Powers: "Engineers for the Atomic Energy Industry," paper delivered June 22, 1950 before ASEE Annual Meeting, Seattle, Washington.

[2] J. D. Luntz: "Education in Atomic Energy," *Nucleonics*, 7, No. 1, p. 3, July 1950.

[3] L. B. Borst: "Opportunities for Engineers in the Field of Nuclear Engineering," *Jl. Engg. Educ.*, *40*, pp. 424–428, April, 1950.

with the adjective "nuclear" made it at once mysterious and placed it practically outside the conventional engineering thinking. Upon reflection, it should be quite clear that the design, construction and operation of any physical system still must follow the same basic engineering principles which we are endeavoring to convey to our students. This was very well expressed recently by Dr. W. E. Kelley, the manager of the New York Operations Office of the A. E. C.[4] "Engineering today is admittedly more complicated than ever before but it is still based upon sound and thorough understanding and application of well-known engineering principles, the kinds of things we learn in the first few pages of the engineer's handbook."

Fortunately, after an upsurge of suggestions to rush into new curricula on "nuclear engineering," it has been fairly well agreed now that it might be too early for any serious consideration of such a radical step. Indeed, a special committee of the American Society for Engineering Education was set up early in 1950 to study the "Implications of Atomic Energy for Engineering Curricula" and to prepare a preliminary report on its findings as guidance for engineering schools which might be pondering the curriculum problem.

Training Specialization versus Broader Basic

It is, of course, true that the attempts to construct nuclear reactors led into many new problems of engineering design, such as purification of the prime fuel, the uranium, a proper subject for chemical engineers; or the design of high pressure pumps which have to handle highly corrosive fluids under conditions where little servicing can be allowed, a challenge to mechanical engineers (including metallurgical engineers); or the treatment and disposal of radioactive waste liquors, a problem with which the civil engineers and particularly the sanitary engineers need to grapple. But these are in fact all old themes appearing in new variations, they are problems for which the progressive engineer, who keeps on growing in his field of study and practice, will find the answer.

How can the progressive engineer develop to be useful in nuclear engineering? How can we prepare him best for this later growth? One way is obviously to modify the conventional curriculum in the direction of nuclear science and related subjects and to brew a new variety with the label of nuclear engineering. The other way is to prepare the student throughout his study in a manner that he can change his field without having to start an entirely new professional life; this requires also changes in the conventional curriculum, but of a different kind.

The choice is then between more specialization and broader basic study.

Specialization is extremely valuable in industrial organizations where ready answers represent direct savings; or in the complex business of law and government where so much is decided by precedent. But specialization means almost automatically a certain narrowness, a loss of contact with the greater world of ideas, of factual relationships, which basically is necessary for real progress. Many of the major contributions in the sciences were made by men who related phenomena in seemingly unrelated fields!

More Branches of Engineering?

Should we deliberately introduce specialization into engineering education beyond the one imposed by the sheer limitations of the capacity of human brains? Have we not gone too far already in this direction by allowing the original four major stems, namely chemical, civil, electrical and mechanical engineering, to split further and establish subdivisions within each of them? The four main stems have a rather natural origin and scope, to wit:

Civil engineering, the oldest of the engineering arts, deals with structures for housing, transportation, and sanitation, i.e., for the requirements of plain civil

[4] W. E. Kelley: "Engineering in the Atomic Age," *Nucleonics*, 7, No. 1, pp. 5–8, July 1950.

life; even the most primitive of social organizations practices civil engineering;

Mechanical engineering, the second oldest branch, is the expression of inventiveness of man to make life easier by creating mechanical implements for all chores; here belong the early waterwheel, the steam engine and the most intricate gas turbine with their tremendous influence upon the more primitive ways of housing, transportation, and sanitation. Application of such machines on a larger scale laid the first and modest basis for the industrial revolution;

Electrical engineering, a relatively young offspring of physics, has harnessed "electricity"—a non-fluid, a substance, if indeed it might be called one, which it is dangerous to collect, which is a myth to the layman, and which is friend to the expert only through proper use of terminal posts!! This electrical engineering is probably the greatest single cause of modern industrial strife and the surest measure of luxury of a nation because it provides untold varieties of subtle stimulation of laziness. It provides probably the strongest spur for a completely materialistic view of life.

Finally, chemical engineering, the youngest of the engineering arts, deals with industrial utilization of chemical processes, many of which had been known since the middle ages, such as preparation of alcohol for various purposes, of glass and glazes, and others. In its modern version, with large scale reactors, its most attractive phases are the preparation of cosmetics, and its most deadly phase is the development of explosives up to the various "atomic" bombs.

Unless man finds some entirely new substance or process, these four divisions seem to encompass all possible diversifications of utilitarian activities. True, in some instances combinations of parts of two or three of these divisions are desirable, but it is very questionable whether one must rush out to create a new kind of engineering, notwithstanding the ambitions of its protagonists.

Broader and More Basic Study

Should we not draw the conclusion that we do not need more specialization but that we do need broader and more basic study? Should not the training be so that the engineering graduate will find it possible to go into any new field, as it opens up during his life time?

Engineering is ever dynamic, ever seeking new and more economic solutions to problems which in themselves are very old, indeed, such as housing, transportation, and sanitation. Thus, engineering education cannot rest satisfied with present knowledge and present practices, it cannot teach the past without projection into the future; indeed, engineering education must be for the future! If we need to explore the use of new materials in the design of an engine, a reactor, or what have you, we turn to the creative engineer who knows how to get the basic data needed for such a design and will carry through on the basis of this data, with well established generic principles. The real professional engineer must be able to see the kaleidoscopic, unending variety of special forms that any one natural law can assume, under the varying conditions of the dynamic technical world.

Now it seems that so-called Nuclear Engineering clearly demands a broad background and training, more so perhaps than certain less active branches of engineering. In a recent paper in the JOURNAL OF ENGINEERING EDUCATION,[3] Dr. Borst enumerated several questions, now rampant, which presumably require entirely new approaches for their solution: "Can we breed fissionable material?"—"What is to be done with atomic ashes that stay hot for centuries?"—"Can we build atomic powered airplanes?" Surely, these are perplexing questions at this point, and their answer might not come from any one kind of engineer, whatever his designation. But then, similar situations have existed before, and we have had

[3] L. B. Borst: "Opportunities in Nuclear Engineering," *Jl. Engg. Educ., 40*, pp. 424-428, April 1950.

to revise the conception of every major stem of engineering, as new ideas arose, and new fields of application opened up.

No amount of engineering training, however specialized or general, can generate by itself ideas in the student's mind. Engineering training can only lay a foundation upon which synthesis of new ideas can be initiated by the catalytic action of the bright mind; and if we need new ideas, we do indeed need the bright minds! The only manner in which we can help as teachers is to create as fertile a foundation as possible upon which the synthesis can take place, and this is certainly not by specialization, by new curricula, by teaching more about less—it can only be done sensibly by broad exposition of the fundamental laws, by recognizing the basic generic principles, from which springs the conception of the problem as a concomitant of its solution!! This is, indeed, the most typical aspect of engineering as contrasted with all other professions: the conception of the problem in a form that spells its solution!

It happens that we have in electrical engineering a perfect illustration of the wrong way of trying to improve upon curricula. With the precipitous development of the radio engineering field, a considerable number of engineering colleges started at once to create two options in electrical engineering: the traditional one for the power field, with practically no change of the good old set of courses, fossilized by practically 20 years of repetition; and a new one for the radio field, which wanted nothing of the heavy machinery courses.

Well, only 10 years ago, preparations started for World War II, and one of the great new problems was "electronic control," such as control of turrets, of antiaircraft guns, of radar tracking devices, of homing torpedoes and so on. A vast new field opened, which required—as if by design—the most intimate combination of power engineering and of electronic engineering. Neither the old-fashioned power engineer, nor the newly-born radio engineer, was equipped to tackle these new problem by themselves. The abler of either class rushed to special courses to balance out the deficiencies created by a premature incision in the curriculum, which disregarded the basic necessity of fundamental training in both fields in order to be reasonably prepared for any new developments, wherever they might come from!

The schools that have had a guiding educational philosophy did provide for a reasonable adjustment to the new developments. Actually, it is fairly well agreed among these latter that undergraduate curricula in electrical engineering should have a maximum of common ground and that the first three years of electrical engineering need not provide specialization. The fourth year might provide optional courses in power, in control, and in communication, with strong advice to secure as broad a training as possible, because of the unpredictable changes in emphasis that might occur in years ahead.

In the graduate schools of electrical engineering, there has been a noticeable divergence of objectives. Some schools consider the Master's program as providing for specialization with intensification of study in a selected narrow field. Other schools, and fortunately a growing number, make the Master's program a very basic one, leading to a critical understanding of the fundamentals. These latter programs include required courses in mathematics and physics so as to permit a broader evaluation of the generic principles, and of their applications, and to emphasize the relatively small number of really basic experimental laws and accepted hypotheses on which the whole structure of any theory rests.

It should be obvious that the second alternative is by far the more suitable for advanced training of engineers, who are to be leaders in research and development, and pioneers in new fields of engineering endeavor. It is the latter group which permits, with relative ease, any adaptation to new combinations of the subject matter of two or more engineering branches.

At the doctoral level, it is generally ac-

cepted that the thesis must be an original contribution to research; however, the course requirements are as diversified as the institutions giving the doctor's degree. In our own case, we practically prescribe a minor in physics, and a minor in mathematics, which we feel to be necessary in order to assure the proper caliber of research work for the doctor's degree.

Training for Nuclear Engineering

How is this all related to Nuclear Engineering? What need be done to the curriculum in electrical engineering to create a practical possibility for the training of men useful in nuclear engineering? Perhaps the answer to this broad question can be given best by way of illustrations.

1. Take first the power aspect. The nuclear power plant as now projected [5] will have the same component structures as any steam-electric power generating station, except that the fuel in the conventional boiler plant (either gas, oil or coal) is replaced by the excess heat of fission. This will, of course, require a number of special safeguards, dealing with the radioactive waste products to prevent the transmission of radioactivity into materials used in the boiler plant, and to protect against harmful levels of radiation by means of shields, etc. As far as the electrical power engineer is concerned, he needs to know about the "hot part" of the plant just as much as he is now learning about the conventional boiler plant for the production of steam by coal, oil or gas; or about the hydraulic installations in the case of hydro-electric plants. He does not need to be a nuclear scientist, nor does he need to really understand the process of fission, in order to appreciate the effects.

On the other hand, if there be a nuclear engineer who can design and construct the nuclear reactor— and this might well be a good chemical engineer—he will certainly not be able to go much beyond the steam pipes connecting to the turbine, without losing confidence in his design ability! It takes the teamwork of the electric power engineer, the engineer for the prime mover, and the engineer designing the primary energy source of whatever nature, in order to build a successfully operating, practical, power plant.

To do his part well, the electric power engineer can get now, in the graduate school in technical elective courses, the requisite knowledge with respect to prime movers and prime energy sources, as far as hydraulic power plants and conventional heat power plants are concerned. This means, then, that some of these graduate courses, like Thermodynamics, Heat Transfer, and Power Supply Economics, should include examples for pertinent nuclear reactor problems, and that elective courses such as Atomic Physics, Nucleonics, Radio-activity should be introduced for full graduate credit.

2. For the detection and measurement of radio activity, many electronic devices have been developed, which belong to the field of "Nuclear Instrumentation" which, in turn, is part of the broader field of electronic instrumentation.[6] Perhaps most important are the instruments used for radiation protection,[7] either direct personnel instruments, or survey meters, or finally, monitors which act as warning devices. Next in importance are the great variety of laboratory meters, counters and recording instruments, some involving highly complicated and specialized electronic circuits.

The so-called eletronics engineer receives in his under graduate years a great amount of basic training in the design of elementary circuits, such as simple amplifiers, oscillators, detectors, and modulators. The important aspects of instrumentation, however, requiring the integration

[5] C. G. Suits: "Development of Useful Power from Nuclear Fission," *Electrical Engineering, 69*, No. 6, pp. 523–528, June 1950.

[6] W. E. Shoupp: "Electronics in Nuclear Physics," Proc. Inst. Radio Engineers, *36*, pp. 1518–1526, Dec. 1948.

[7] K. Z. Morgan: "Instrumentation in the Field of Health Physics," *Proc. Inst. of Radio Engineers, 37*, pp. 74–82, Jan. 1949.

of the elements into systems, necessarily goes beyond the scope of the four-year program; they are taken up in several elective graduate courses, into which, of course, applications of nuclear instrumentation can well be included.

3. The dangerous intensities of radiation close to the observed physical phenomena and chemical reactions, both in the experimental laboratory, as well as in the nuclear furnace, make it necessary to institute remote control in rather elaborate fashion. Again, the specific problems belong to the now well-established field of servomechanisms, or better, "feedback control systems." Because of its general importance, and its basic relationship to electric power and electronics, attempts are being made to include an introductory course in the senior year as one of the technical options. Courses of more or less advanced type are practically standard in the graduate electrical engineering curricula, and hardly need modification to be of direct service to nuclear engineering. This covers also the observation of the physico-chemical interactions by applying stereoptic television so as to actually "see" phenomena, and yet be located outside the range of harmful radiation.

Thus, the entire scope of graduate electrical engineering training will eventually be related to the problems of nuclear engineering. To be of greatest service, the electrical engineer, inclined to work in the field of nuclear problems, should take the opportunity of learning the principles of nuclear physics, without necessarily becoming a "nuclear engineer." But the burden of this training must be on the graduate level, since it cannot be placed upon an undergraduate curriculum of four years. Even the extension of engineering programs to five years has rarely been used to give greater range of technical education; it is usually designed to add more of the general education in history, economics, languages and the like, in order to restore some balance to the educational diet.

Conclusion

I strongly feel that if we give to the young bright people a solid foundation of fundamental knowledge in the undergraduate school, and impress the fact of the dynamic development in science and technology, we can rest assured that they will be able to branch out into all the attractive and challenging new fields, with vigor and intelligent imagination. It is not necessary and, indeed, it might be harmful to stress specialization at too early a point in the educational program. In the end, progress in Engineering as well as in Science depends upon new ideas, and these germinate best in the rich soil of broad and fundamental knowledge.

Agricultural Engineering Curriculum at the University of Illinois*

By E. W. LEHMANN

Head, Department of Agricultural Engineering, University of Illinois

The end point in any program of education is action. That is, the fundamental purpose is to get people to act properly under all circumstances; do a better job; and be responsive to the needs of and to serve society. The purpose of a specialized engineering curriculum is to get people to "perform" better within a particular field. To attain this objective in engineering, the individual must be interested, enthusiastic and informed, and also have a competence in technical training and skill within the field of specialization in which he expects to find employment. This statement should be considered an argument for the provision of options, and not a debate on the relative merits of the general curriculum and the option plan, both may be needed.

We look to the home, the church, and the elementary and high schools to educate people to live and to act properly. We also expect everyone to have some basic knowledge of mathematics, physics, social and life sciences and some ability to express himself clearly. In a large part, education will continue to be a responsibility of the home, the church, and the elementary and secondary schools. It should be recognized that many of our most progressive and successful citizens never went to college.

Many students enter colleges of engineering, however, without a clear-cut purpose or an understanding of many life problems. They lack the disciplines which are essential to a well-trained engineer. Fortunately, most students who enter agricultural engineering have a reasonably good idea of what they want to do, and when they finish the sophomore year, they know the branch of agricultural engineering for which they want to prepare. They recognize that there is as much difference between a job in the implement industry and a job in the farm structures field as there is between mechanical engineering and civil engineering. They recognize that the agricultural engineering "major" in either of these divisions provides the same basic technical training with additional courses that better qualifies them for the work they want to do than if they followed the curriculum in either mechanical engineering or civil engineering.

Early Problems

The earlier graduates in agricultural engineering, many of whom went into college work, did not recognize the clearly defined divisions of agricultural engineering. Many departments were small; some were one-man departments. This man had to develop and teach all branches of agricultural engineering. Under such circumstances, the need for a general training that cut across all branches of agricultural engineering can be easily understood. Courses in farm machinery and farm buildings dealt largely with ap-

* Presented before the Agricultural Engineering Division of the ASEE at the 59th Annual Meeting, Michigan State College, June 28, 1951.

plication, practical design and functional requirements, with little attention to research, theoretical design, and development. At that time, little or no attention was given to crop processing, rural electrification and soil conservation.

The majority of the agricultural engineering graduates who went into industry during this early period were selected for positions where their knowledge of agriculture and a broad understanding of engineering were more essential than specialized technical engineering training. This apparently remains true in certain work, but not where a high degree of engineering competence is required.

Trends Toward Specialization

Now agricultural engineering has become much more highly specialized. Individuals who work in the college departments make their contribution when they concentrate their attention on subject matter within a relatively limited area. This specialization corresponds more nearly to what has existed for some time in the older branches of engineering.

It is evidenced in the technical sessions at the annual meetings of the American Society of Agricultural Engineers and by the demand for graduates with special training. At the technical agricultural engineering meetings, there are a few joint sessions which emphasize the relationships which exist between the different technical branches of agricultural engineering. For example, a good soil conservation practice may require a change in machinery design. In advancing rural electrifiaction, the farm structures specialist has the ability to plan buildings to make equipment installation and power application effective.

We have men who are nationally recognized in the farm structures field; the same is true of men in the farm machinery field. These men would not presume to be equally qualified in other fields as in their speciality. It is likewise true of men in narrow fields of civil engineering and mechanical engineering.

Only in recent years has the farm machinery industry looked to the agricultural engineering departments for men qualified as farm machinery designers. They want men who are definitely interested in this specific area of work.

We find that agricultural engineering students who expect to do engineering work want specialization. Moreover, we believe it is essential that they have such specialization to be sufficiently competent to meet competition. The demand by employers for men with specialized training comes not only from farm implement companies who want men to do farm machinery design, developing, testing, or research work but from other organizations who also want men trained in specialized lines. For example, in a recent contact with a representative of a fuel company, I was told they wanted to employ a man trained in power and machinery. This employer was not interested in a broad training covering the whole field of agricultural engineering. Likewise, the rural electrification superviser of a large public utility company was looking for an agricultural engineer who had majored in farm structures. It seemed essential that he should have a farm structures man on his staff to solve problems involved in planning the installation of equipment to improve labor efficiency around the farmstead. A large manufacturer of tractors and earth moving equipment recently selected two Illinois agricultural engineering graduates whose major was in structures and soil and water engineering, in preference to two civil engineers.

The student who completes the requirements for a B.S. degree in Agricultural Engineering under the option plan is better prepared for graduate work in the particular field in which he has majored. To be able to take the advanced graduate courses in design, it is essential that the necessary undergraduate prerequisites be

taken. Agricultural engineers who graduate at the University of Illinois are qualified to major not only in agricultural engineering but in either mechanical engineering or civil engineering, depending on the option completed. With these qualifications, they may proceed directly toward the Doctor of Philosophy degree in either of these areas of specialization.

We believe an agricultural engineer should be well trained in at least one phase of subject matter to adequately serve his company, his clients, or the public, and to meet effectively the competition of men graduating from other branches of engineering.

Areas of Specialization

It is generally recognized that agricultural engineering covers at least five divisions or areas of specialization. The four most common are: Farm power and machinery, farm structures and housing, soil and water engineering, and rural electrification. The fifth is crop processing. The latter is largely a mechanical operation, utilizing the basic principals of physics, thermodynamics, heat transfer, air flow, and power application.

To be well trained in one field, the engineer should be qualified to do design in this field. If it is required that he have approximately equal training in all agricultural engineering subject matter divisions, it becomes impossible within a 4-year period to take sufficient training to become thoroughly qualified to do design work in any one of them. At least, the student completeing the general curriculum cannot be expected to have equal or greater ability than the structural engineer who graduates in civil engineering, or the machine designer who graduates in mechanical engineering.

The practice of providing options in other curricula is well established. In civil engineering, for example, there are construction, highway, hydraulic, railway, sanitary and structural options. In electrical engineering there are electric power engineering , communications and electronic engineering, and illumination engineering options.

To meet the engineering needs of agriculture, we have provided only two options. Our reason is that two or more branches of agricultural engineering are so closely related, they require the same basic training, they can then be correlated and integrated into one program.

First, let us consider the option of farm structures and soil and water conservation. In both of these, basic training in structural design and materials is essential and important. Civil engineers who take similar training are employed in the same fields, but *they lack the agricultural training and the applied agricultural engineering courses.*

In the power and machinery option the students have the same basic training as is given to mechanical engineers and the same sequence of mechanical engineering design courses. To qualify them further for work in the tractor and implement industry, they are required to take courses in farm machinery design, farm power, and special problems. We are confident that the students who complete this option are better trained for the implement industry than are mechanical engineers.

High School Preparation

A curriculum is not statie, but always dynamic; it should be and is subject to change. At the University of Illinois the curriculum is now in process of change to meet the present demands. High schools will assume a greater responsibility for the training in mathematics. Community, state, national, and international problems require that we do something to provide more training in the humanities and social and life sciences. An effort is now being made to provide at least one broad educational course each semester.

In agricultural engineering, we now have 14 semester hours required in the latter group. To attain the objective of 24 hours, which "cannot be attained" according to some engineering staff members, we must adjust our requirements in agricultural engineering to provide additional hours for electives and the general courses. This can be more easily done under the option plan.

At present, the option plan permits the student not only to take the basic courses taken by all engineering students, and the essential basic courses in agriculture, but also a series or sequence of engineering design courses: (1) a series of 14 semester hours in civil engineering design, in conjunction with, or prerequisite to advanced work in farm structure, and soil and water engineering, or (2) a sequence of 14 hours of mechanical engineering in thermodynamics, mechanics of machines and machine design, along with the advanced farm power and machinery courses.

In the option plan, approximately two-thirds or 96 credit hours of the required work in the agricultural engineering options is *identical* with the requirements in either civil engineering or mechanical engineering. This includes approximately thirty hours of advanced engineering subjects in the junior and senior years. There are 48 hours of either option courses or electives in the fields of specialization.

The basic agricultural courses include farm crops (four hours), soils (five hours), and farm management (three hours). These are a part of the training of an agricultural engineer in each of the options or specialized fields.

To make clear the close adherence to basic engineering curricula, and yet show the agricultural engineering specialization, the following comparison of the farm structures and soil and water engineering option in agricultural engineering with the general option in civil engineering is used as an illustration:

HOURS COMMON TO THE TWO CURRICULA

	Agricultural Eng. (Semester Hours)	Civil Eng. (Semester Hours)
Freshman year identical	37	37
Sophomore Physical Education and Military	4	4
Sophomore Mathematics	8	8
Physics	10	10
Electrical Engineering	3	3
Economics	3	3
Theoretical and Applied Mechanics	13	13
Identical Civil Engineering Courses	18	18
Total	96	96

HOURS NOT COMMON TO THE TWO CURRICULA

	Agricultural Eng. (Semester Hours)	Civil Eng. (Semester Hours)
Surveying	3	10
*Geology	3	3
Botany, Crops, Soils, and Farm Management	15	0
Mechanical Power Equipment	0	3
Introductory Agr. Eng. Courses	6	0
Specialized Courses	15	18
Approved Electives	6	14
Total	48	48
Total Required for Graduation	144	144

* Agricultural engineers are permitted to take either Agricultural or Engineering Geology.

It should be recognized that with a "narrow stem" of agricultural engineering training in the junior and senior years affords an opportunity for more electives than is possible in a curriculum that covers the general field of agricultural engineering. This is a decided advantage in meeting the demands for more training in the social and life sciences, humanities, and free electives.

Engineering curricula are notoriously deficient in these courses. Curricula that do not attempt to cover the whole field of

agricultural engineering subject matter make possible specialized training in agricultural engineering and a broader training in other fields of subject matter. This means greater competence in at least one division of agricultural engineering, and better training to meet other life problems.

Conclusion

In conclusion, we should recognize that:

The public not only expects a reasonable success vocationally or professionally of all college and university trained engineers, but also expects that they shall assume a certain amount of leadership in local, county, and state affairs.

It is a mistake to assume that the student who arrives on a college campus has attained from his home and secondary and high school training the competence needed in citizenship, in human relations, and in living. The option plan will permit a broad training in life and social sciences, and in the humanities.

It is possible to secure competence as a designer of either machines or structures in a four year curriculum with options and with a broad base of fundamental engineering training, but such a curriculum does not permit competence in all branches of agricultural engineering.

The various technical branches of agricultural engineering are just as precise and deserve as thorough technical training as branches of other fields of engineering.

The agricultural engineer must have a greater competence in the field of farm machinery design or farm structures design than other engineers if we are to have a feeling of assurance that the agricultural engineering curriculum is justified.

The agricultural engineer, like engineers in other branches of engineering, is expected to be able to function either in designing, testing, developing, and servicing in the machinery and power field; or in designing and construction of farm buildings and structures in the soil and water engineering field. In either option with electives, he may qualify for rural electrification work.

Whether he be trained in one option or in the other, he may do research or sales work, or he may cast his lot in the field of education as a teacher. Finally, with years of experience and demonstrated ability and an understanding of the policies, personnel, finance, public relations, and other general problems of his organization, he may function in a supervisory capacity or as an executive.

For most of these functions, we believe the agricultural engineering curriculum with a specialized option provides the best training.

Preparing an Engineer for Sales Work*

By JOHN GAMMELL

Supervisor of Sales Training, Allis-Chalmers Manufacturing Company, West Allis, Wisconsin

Two thousand years ago the founder of our Christian era and, no doubt, the greatest salesman of all, said that—"He who would be first among you, must be servant of all." We think this is a good motto and a good description of an ideal technical salesman. Another way we look at a technical salesman is to consider him as an itinerate educator—a man who brings the ideas and knowledge of the factory specialist to the operator in the field. This works both ways, too, in that he brings the problems of the field to the design and development specialist at the factory. A technical salesman is an excellent example of free enterprise at its best. If anyone gets an idea anywhere in this land of ours, you can pretty well rest assured that some salesman somewhere will pick it up and see to it that it is developed by whoever has the proper know-how and facilities to do the developing. If the idea or the device doesn't work as well as some other salesman's idea or device, it is dropped. We think this is a wonderful system. We understand that Joe Stalin and the communists don't like salesmen and consider them one of the prime wastes of the capitalist countries. We don't see how there could be a better way of floating ideas and problems around the country than the way we do it.

Now in order that a salesman carry out this function of being a servant to everyone, of being a disseminator of ideas, of being a catalyst between problems and solutions, he has to have some pretty well defined characteristics. One of the most important of these is to be able to talk easily and naturally about the type of things with which he is concerned. The first problem then in the preparing of an engineer for sales work is to see to it that he is ready, willing and able to clearly convey ideas by speaking to either one person, a dozen people, or a thousand people if need be.

Training Program

In working with those who have been selected as having an aptitude for sales, we suggest that they join public speaking clubs, take public speaking courses, and in general be aware of the power of words. We impress upon them that it isn't how much they know that counts in talking to people, or even how much they tell someone, but how much they are able to say that the other men will understand and remember. In other words, you can read an electrical handbook to a man but it doesn't make him an electrical engineer. All of you have had the experience of hearing people talk about technical matters time and again in which not more than 25 or 30% of what was said was understandable during the discussion. It might be marvelous material for a book or a paper, but for a discussion it falls flat.

In addition to encouraging our prospective salesman to join public speaking classes, we have classes of our own

* Presented before the Industrial Engineering Division at the 59th Annual Meeting of the ASEE, June 28, 1951, Michigan State College.

on company time during which period primarily what we do is to have the future salesman talk about machinery and its application, which is our business. We have other students evaluate his presentation and ask him questions and supplement his talk when they feel that he has left out something of importance concerning the problem at hand.

We show motion pictures, sound slide films, models and generally make use of all the sales gadgetry available.

There is a great deal of talking today about the professional attitude or professional approach. There are many facets to this thought but on the purely technical side, I am impressed by an idea put in my mind by one of my associates, which, incidentally, might also illustrate one of the differences between a technician and a professional engineer. When my associate first started to sell, years ago, he told me he used to get a considerable quantity of orders for centrifugal pumps in which someone would ask for a pump to deliver so many gallons of water at such and such a presure. It seemed to him that since we were in business to sell pumps, we should take the order and make the delivery as expeditiously as possible. His boss said no, that in each case he should call the buyer, or, if possible, go out to see him and find out what he really was trying to do. For instance, a man needs so much water at such and such a presure at such and such a time and place in order to perform a certain operation. To start out with, there may be a better way of performing the operation so that he doesn't really need any water at all beyond what he uses at present. Of course, no salesman indicates to a buyer that he doesn't know what he wants but his attitude is that of a man who is genuinely interested in his customer's problems and is dedicated to the idea that there is always a better way of doing things and that he wants to be sure he has the best way.

With further regard to the application, there are such simple factors as—is it going to operate 24 hours a day, 365 days a year at a maximum capacity, or just 5 minutes a day. In the former case, obviously, a very high efficiency unit is needed; in the latter case, efficiency is hardly a point. Is the pump going to be in series with the other operations in the man's plant in such a manner that if this particular pump fails, the plant has to be shut down, or is it in some parallel function? In one case, complete reliability and serviceability are the important features and the man is not apt to be concerned about the economics of a better and more expensive design. The kind of trouble he has had in the past—and everybody always has troubles—is another factor. Nothing lasts forever and nothing is 100% efficient. Anything short of this is, in a way, trouble. In addition, there are the more common types of difficulties such as premature breakdowns, faulty material, excessive wear, etc. Surely any man with a professional mind wants to know how a man's doing the job now and the difficulties he has had in order that he may be in a position to better overcome them. The professional man has an inquiring mind—he wants to know the problem. He wants to get beyond the "how" and get to the "why."

We infiltrate these ideas in the minds of the potential salesmen in classes of a somewhat formal nature in which, as we mentioned above, the prime idea is to have the student talk about our business.

Community Participation

The truly professional technical salesman should have some imagination, some understanding and some interest of the scope of engineering beyond the immediate environments of his job. We encourage our embryonic sales engineer to carefully select a few of the principal technical and professional organizations of his community, become a member of them, and take part in their activities. We suggest to him that he follow magazine articles on such broad engineering

matters as atomic power, guided missiles, the use of new metals such as magnesium, aluminum, titanium, etc. The changes in the steel industry brought on by the depletion of iron ore in Minnesota should be of interest. This matter of steel production brings up a host of topics which should be intriguing to an engineer—such as the South American and Labradorian iron reserves, steel plants on the East and the West Coast, the pros and cons of the St. Lawrence Seaway. The electric power industry is another industry worthy of study. It has had a truly phenomenal growth. We think this growth should be of interest to any engineer since it touches the engineering world in many points. The industrial and population movements such as to the Southwest and the Pacific Coast must needs be of interest to the sales engineer.

Gas turbines, jet propulsion, guided missiles and even such futuristic items as the possibility of rockets to the moon and earth satellite bodies are in the legitimate field in which any sales engineer should be able to carry on a discussion. In short, a sales engineer should be a man of breadth and imagination. If he is the type of man who wants to probe deeply into one subject to the exclusion of others, then he should not be in the sales field. However, sales requires men who are capable of going deeply in different fields in case it is necessary. Their motivations are, however, broadly scientific but not deeply so. A perfectly sound training would develop a man who is quite well informed on one subject and generally acquainted with many.

In this discussion we have talked very little on the details of strictly technical training but, rather, stressed the broader aspects. We have done this because we believe that most educators and trainers are entirely capable of teaching intelligent people any technical subject on which any volume of information has been developed. It is a matter of how much time and attention you have available for the purpose. In our company we spend two years in rotating salesmen to different plants and different departments. Most of them work in 15 to 20 selected locations, travel to 4 plants, undergo about 20 weeks of lectures interspersed with other work, review numerous movies and sound slide films, etc.

In all of our training we are very careful not to give the impression to the trainee that we are running the place like a Prussian Drill Master. We feel that he is a mature individual who has had 16 years of education and that he undoubtedly has some very good opinions of his own concerning how his training should be conducted. We carefully select our sales trainees on the basis of preference, aptitude, intelligence and personality tests together with a series of six to seven interviews. If he shows up as a salesman and, most important of all, if he feels that he has the proper characteristics for it after these tests and interviews, then we are pretty much inclined to feel that he is a good bet. Once a man has gone through this type of a mill, we hope he has the inner confidence of knowing he is in exactly the right field and that he is an outstanding individual with an unusual chance for success in the area in which he has chosen to work.

In choosing the particular training locations, lecture courses, etc., we do not tell him—you take this location or that one—but, rather, we ask him what type of work would best accomplish rounding out his background. We feel that he is in a better position to know his defects than anyone else. We can certainly help him, and we do make suggestions; but it is his life that is being molded and the choices must needs be his. If he makes a mistake and fails, then, of course, it is too bad; but if we make a mistake and ruin his life, it is a tragedy.

To go back to another aspect of sales training, we believe that good salesmanship begins with product knowledge but it doesn't end there. The peculiar problem of the salesman is how to disseminate engineering information effectively to

other people so that it can more greatly contribute to the very good result of better living for all.

Let me close with one more thought. Mr. Emerson, the essayist, more or less said one time that you can't get something for nothing in this world except *the will to do.* There is no magic in preparing engineers for sales work but a lot of ingenuity and hard work does help and *above all you must impart the will to do.*

College Notes

The General Electric Company has established an annual mathematics fellowship program under which secondary school mathematics teachers may take summer courses at **Rensselaer Polytechnic Institute**, it was announced here today. Dr. Livingston W. Houston, president of Rensselaer, said that there will be 50 fellowships awarded to teachers from 12 eastern states and the District of Columbia for a six-week program from July 7 through August 16, 1952. The program is designed to familiarize secondary school mathematics with the applications of mathematics to the various fields of human endeavor. It will be conducted by the Rensselaer faculty in co-operation with General Electric scientists and engineers, he explained.

Awards for the eighth annual **General Electric Science Fellowship** under which high school science teachers attend a specialized summer session at **Union College**, will be made early in 1952, it was announced here today. Dr. Carter Davidson, president of Union, said that 50 fellowships will be awarded to teachers from 13 eastern states and the District of Columbia for a six-week program from June 30 through August 8, 1952. The program, which has graduated some 350 teachers since its inception in 1945, is designed to acquaint participants with new developments in science and to provide a clearer understanding of how scientific principles are applied to industry.

Preparation for Petroleum Geology and Geophysics

By JAMES T. WILSON

Associate Professor, University of Michigan

Introduction

Geology is the study of the earth by all available means. Consequently it uses information and methods from the other sciences—particularly from chemistry, physics and biology. Geophysics is the application of physics to geological problems, and thus is but a phase of geology. However, the training of a professional geophysicist involves such a thorough grounding in physics as to make it a borderline field.

The scope of geology may be visualized by considering the sub-fields into which it is divided. These are: *Petrology and mineralogy,* which are the studies of rocks and minerals; *Physical geology* or the study of the various processes such as erosion and volcanism; *geomorphology,* which is the study of the development of landshapes; *stratigraphy and historical geology,* which deal with rock sequences and the history of the earth; *paleontology,* which being a study of ancient life is closely allied with historical geology; and *economic and engineering geology,* which depend upon all of the other branches. *Geophysics* and its parallel, *geochemistry,* might also be included. *Structural geology* or the study of rock structures resulting from deformation is included here with physical geology although its importance might warrant giving it separate classification.

Professional geologists are likely to classify themselves as petrographers, structural geologists, stratigraphers with leanings towards either paleontology or structure or both, paleontologists, economic geologists, etc.

The list of original member societies of the American Geological Institute gives a further insight into the scope of the science. These are: the Geological Society of America, the Mineralogical Society of America, the Paleontological Society, Society of Vertebrate Paleontology, American Association of Petroleum Geologists, American Institute of Mining and Metallurgical Engineers, Society of Economic Geologists, Society of Economic Paleontologists and Mineralogists, Society of Exploration Geophysicists, the American Geophysical Union, and the Seismological Society of America.

The paragraphs above indicate that geology is a broad field and that an adequately trained geologist must be quite familiar with several cognate sciences. It is evident that petrographers must be well grounded in chemistry and paleontologists in biology. In fact to a large degree the increasing specialization of geologists is an outgrowth of the need for extensive training in related sciences and because of this it is no longer easy for a geologist to be both a paleontologist and petrographer or a geophysicist and a stratigrapher. There are, of course, certain groupings, as stratigraphy and paleontology, petrography and geochemistry, etc.

Petroleum Geology and Geophysics

The petroleum industry is most interested in those phases of geology that will furnish information about the origin and accumulation of petroleum and natural gas. These materials originate in sedimentary rocks and the accumulations

of economic importance form where they have migrated through the rock and become concentrated in the pore spaces of porous permeable reservoir rocks. The accumulations are in so-called "traps" where the arrangement of the reservoir rock and surrounding impervious rocks has led to concentration of the oil and gas. These traps are of two main types—structural resulting from the folding or faulting and stratigraphic where there have been interruptions in the orderly sequence of deposition of sedimentary rocks. Clearly then structural geology and stratigraphy are the important fields of geology for the petroleum industry. Because both paleontology and geophysics offer valuable tools for the unravelling of details of structure and stratigraphy they too find an important place. Petroleum geologists are likely to be either stratigraphers with paleontological or structural leanings, or to be geophysicists. It is rather difficult to be both.

Curricula at the University of Michigan

For a number of years the Geology Department at the University of Michigan has considered a fifth year beyond the Bachelors degree essential for adequate training for a career in geology. This extra year leads normally to a Masters degree. Our department is in the Literary College (as are most geology departments in the United States) and about one-third of the undergraduate course selections must be in non-science courses. I feel that this is to the student's advantage but it is one of the reasons for the fifth year of study. The curricula discussed below assume this extra year of work.

As basic cognate sciences all geology students must have a year each of college chemistry and either college physics or zoology. In addition they must have credit for mathematics through trigonometry. unless their interests are definitely paleontological they are urged to complete a course in calculus. Students whose primary interest is in geophysics must have mathematics at least through differential equations and additional courses in physics or engineering. It is obviously desirable for all students to have additional chemistry, zoology, physics, and mathematics but there is just so much time. A few years ago a symposium on geological training led to the conclusion, when all conferees suggestions were totalled, that about fourteen years of university work would see a student through the courses he needed.

The basic core of geology courses, beyond the beginning ones in geology and mineralogy, includes a semester each of structural geology, petrology, geomorphology, geological map interpretation, paleontology, and introductory geophysics. In addition a summer session at the field station in western Wyoming is required.

Except for those students showing an early interest in a specific field there is little opportunity for any specialization before the fifth year. Any concentration of interest before that time should, in any case, be directed towards the appropriate cognate sciences. The graduate year may show considerable specialization. Petroleum geologists will usually elect a professional course in the subject and, in addition, will take such courses as sedimentation, advanced structural geology, stratigraphic paleontology, micropaleontology, and geophysical prospecting. Geophysicists will take considerably less geology in their year of specialization but will elect additional courses in mathematics, engineering and physics. A thesis is required for the Masters degree and this permits some further concentration of interest.

It is my opinion, and I feel also the opinion of many oil company geologists, that the background of fundamental sciences and basic geology courses is the most important part of a student's training. I have noticed that a student with forty hours of chemistry, physics, and mathematics, and forty hours of geology will get a better job quicker than a student with twenty hours of the basic sciences and sixty hours of geology.

In the News

Annual Meeting of ECPD

Engineers and engineering educators met in Boston's Hotel Statler, October 19 and 20, for an annual report on the status of the engineering profession. The occasion was the 19th annual meeting of the Engineers' Council for Professional Development, with H. S. Rogers, President of the Polytechnic Institute of Brooklyn presiding.

One of the features of the meeting was a session of the training committee featuring six speakers. They reported on various phases of a six-point training program introduced last year by ECPD to aid young engineers in their first five years in the profession. The program, on which the group plans to spend $20,000, a year, proposes guidance to the young engineer for an adequate development plan in six important areas of professional life. The areas are: in-service training; continued college education; community service; professional registration; self appraisal and selected reading. Those speaking on the training panel were: H. P. Hammond, Dean Emeritus, Pennsylvania State College; J. K. Walter, Training Supervisor, West Penn Power Co.; J. C. McKeon, Manager, University Relations, Educational Department, Westinghouse Electric Corp.; K. B. McEachron, Jr., Manager, Technical Education Division, General Electric Co.; C. S. Crouse, Head, Department of Mining and Metallurgical Engineering, University of Kentucky; F. N. Entwisle, Director, Testing and Guidance Division, Newark College of Engineering.

Another panel discussion on engineering guidance, was held under the direction of Willis F. Thompson, chairman of ECPD's guidance committee. This committee has developed a plan to cover the nation with a network of state committees to disseminate information on effective methods for guidance in engineering, and the first part of the panel was devoted to a detailed account of this development. This was followed by a panel discussion on, "The High School's Point of View on Guidance," featuring three educators from the Massachusetts state school system: Frederick A. Small, Principal, School Department, Norwell, Mass.; Thomas D. Ginn, Director of Vocational Guidance, Boston School Committee; Aaron Fink, Guidance Director, School Department, Stoughton, Mass.

Other highlights of the meeting were a dinner address by Eugene W. O'Brien, Vice-President, W. R. C. Smith Publishing Co., who talked on, "What Junior Engineers Find Important," a luncheon talk by Harold B. Richmond, Chairman of the Board of General Radio Co., on, "Observations on Cooperative Course Training as Viewed by a Manufacturer," and a Saturday luncheon talk by James Rhyne Killian, Jr., President, Massachusetts Institute of Technology.

Additional reports of committees included—education, recognition, information, ethics, and unity in the engineering profession.

The national organizations comprising ECPD are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Chemical Engineers, National Council of State Boards of Engineering Examiners, American Institute of Electrical Engineers, and The Engineering Institute of Canada.

Minutes of the Executive Board Meeting

A meeting of the Executive Board of The American Society for Engineering Education was held on Wednesday, November 14, 1951, at the Rice Hotel, Houston, Texas. Those present were: S. C. Hollister, *President*, M. M. Boring, A. B. Bronwell, L. E. Grinter, G. A. Rosselot, C. L. Skelley, and B. Bowen.

Report of the Secretary

The Secretary presented a written progress report on the current projects and developments of the Society. This is summarized in the Minutes of the General Council meeting of November 14, 1951.

Report of the Treasurer

The Executive Board reviewed the final audit of the Society. The audit showed a net loss of $311.07. By previous action of the Executive Board an amount of $1,315.03 was transferred from the ECRC Reserve and $1,486.45 was transferred from the Special Projects Reserve to defray part of the cost of printing the ECRC *Directory of Research*. When these adjustments were made, the income and expense statement showed a net balance of $2,490.41, which was transferred to the general surplus of the Society.

The financial statement as of November 7, 1951 showed that receipts and disbursements were in line with those of the corresponding period for 1950.

The Treasurer and Secretary presented graphs showing the trend of income and expense over a ten year period. The following is a tabulation of the comparative income and expense for the years 1940–41 through 1950–51.

	1940–41	*1950–51*	*Per cent Increase*
INCOME			
Total income	$20,231.62	$60,317.02	295%
Dues of members	16,994.36	39,113.20	230%
Advertising	2,503.51	9,401.38	370%
EXPENSE			
Total expense	$18,686.28	$60,628.09	325%
Cost of publications	7,002.72	24,139.43	345%
Office salaries and clerical assistance	6,000.00	11,018.44	180%
Office expense and travel	2,001.97	8,117.63	400%
ECAC, ECRC, conferences and meetings, etc.	3,681.59	17,352.59	472%

The following conclusions are to be drawn:

1. The vigorous membership campaign during the past five years has practically doubled the number of individual members in the Society. The increased revenue resulting from this expansion of Society membership has succeeded in keeping income in line with rapidly rising costs.

2. The advertising revenue has increased substantially, partly due to new advertising contracts and partly due to increased rates and volume.

3. It seems evident that the Society cannot anticipate in the future the large increment of new members each year which was experienced during the past five years. The reason is that declining enrollments in engineering colleges are causing a shrinkage of engineering faculty members. There are certain areas of potential membership which offer promising possibilities. These include: (a) industrial members, (b) younger faculty members of instructor and assistant professor rank, and (c) faculty members in junior colleges and technical institutes. An effort will be made this year to expand the membership in these ranks.

4. One of the promising areas of increased Society participation and revenue is that of Associate Institutional members, from among industries of the country. A Committee is being formed, under the chairmanship of Jesse McKeon, Westinghouse Electric Company, to solicit Associate Institutional memberships in the ASEE.

5. The increase in expense is due to: (a) the increased scope of activities of the Society, (b) the enlarged membership, and (c) inflationary costs. The principal single item of expense is the cost of publication of the JOURNAL, which has tripled in ten years.

The Executive Board authorized the Secretary and Treasurer to make a projected study of the Society finances for the next five years, based upon proposals to enlarge the Secretary's office.

Adequacy and Standards of Engineering Education

President Hollister proposed that the various curricular Committees and Divisions of the ASEE conduct a critical investigation of the adequacy and standards of the engineering curricula, with a view to projecting the thinking into the needs of the engineering profession in the years ahead. Major stress would be given to those elements of the curriculum which give continuous and lasting support to the graduate's professional life. Particular attention should be devoted to an inquiry into the adequacy of the scientific foundation in the engineering curricula.

It was recommended that this study enable the engineering colleges to participate actively in the study of their curricula and the extent to which these are meeting the professional needs of the graduate. It was proposed that a national committee be appointed to coordinate the program and provide stimulation and direction.

It was voted to appoint a committee of the ASEE to implement the program on evaluation of the adequacy and standards of engineering education.

Program of Cooperation with Secondary Schools and Junior Colleges

Vice President Boring reported that the meeting of the Upper New York Section of the ASEE was devoted to education and utilization of engineering manpower. This included discussions of the problems from the view point of secondary schools and junior colleges. The panel discussion was transcribed and has been sent to ASEE Section chairmen in the hopes of stimulating similar programs in other Sections.

Mr. Boring also reported that the Edison Foundation is sponsoring and financing a program in which selected secondary school teachers are invited to attend conferences for the purpose of discussing ways and means of strengthening scientific education in the secondary schools.

Vice President Boring suggested that the program of establishing cooperative working relationships with secondary schools and junior colleges be carried directly to the Sections and that they in turn develop methods of implementing these relationships on a regional basis. He stated that a relatively small national committee might be used to coordinate the activities of the local groups.

Report of the Committee on Improvement of Teaching

Vice President Grinter stated that a first draft of the report of the Committee on Improvement of Teaching had been submitted to the Committee members for criticisms and that it was hoped that the final report would be completed during the year.

The Board voted to authorize the Committee on Improvement of Teaching an appropriation of $750 for the preparation of the final report.

Plans for the Annual Meeting

The Board decided to hold general sessions at the Annual Meeting on Tuesday, Wednesday, and Thursday mornings. One morning would be devoted to a general session of the Society as a whole and the other two mornings would be devoted to general sessions sponsored by the ECAC and ECRC.

Secretary Bronwell reported that Dartmouth has adequate housing facilities for up to 2200 persons. This seems ample in view of the attendance of previous ASEE Annual Meetings. The local committees have been appointed and are drawing up plans for the Annual Meeting.

Enlargement of ASEE Headquarters Staff

President Hollister reported that he felt that the Society should be exerting more influence on the pressing national problems bearing on engineering education. To take

on this responsibility involves increased contact with governmental organizations and industry. With the increased responsibility of the Society, it will be necessary to increase the headquarters staff of the ASEE in order to relieve the Secretary of some of the routine work and free him for more important contact work.

Up to the present time, the Secretary's office has employed the Secretary on a part-time basis and two full time office secretaries. This seems inadequate for a national society of over 7000 members, since the Secretary's office is required to: (a) take an active part in the administration of the major projects of the Society, (b) coordinate activities of the Committees, Divisions, Sections, and Councils of the Society, (c) edit the papers for the Journal and handle the advertising, (d) make arrangements for the various meetings of the Society, including the Annual Meeting, (3) be responsible for all receipts and disbursements, including the annual audit, and (f) service the Society membership, including information requested, dues notices and receipts, etc.

The Board recommended the addition of a part-time assistant to the Secretarial staff to take on some of the editorial and other responsibilities. In order to enable the Secretary to enlarge upon his outside contact work, the Board

Voted to authorize an increase in Secretarial travel funds not to exceed $1000 for the current fiscal year.

Applications for Institutional Membership

The following applications were approved for institutional membership in the ASEE: University of Mississippi (active); St. Louis University (active); Lowell Textile Institute (active); University of Omaha (affiliate).

Request of Civil Engineering Division for Summer School in 1952

The Secretary read a letter from Professor Gaylord, Chairman of the Division of Civil Engineering, requesting the Executive Board to approve two summer schools, one in Surveying and Mapping and the other in Sanitary Engineering.

It was voted to authorize ASEE sponsorship of a summer school in Surveying and Mapping and another in Sanitary Engineering, subject to the Civil Engineering Division's desire to sponsor these summer schools. The matter was referred to Dr. Grinter to work out the details with the Civil Engineering Division.

Other Business

The following items of business were discussed at the Executive Board meeting and recommendations are embodied in the Minutes of the General Council meeting of November 14, 1951.

(a) Report of the Teaching Aids Committee.
(b) Formation of a Public Relations Committee.
(c) Committee on Contract Relations with the Federal Government.
(d) Participation in UNESCO.
(e) Associate institutional membership drive.
(f) Mid-year meetings of ASEE Divisions.

Respectfully submitted,

ARTHUR B. BRONWELL,
Secretary

Minutes of General Council Meeting

A meeting of the General Council of The American Society for Engineering Education was held on Wednesday, November 14, 1951, at the Rice Hotel, Houston, Texas. Those present were President S. C. Hollister, M. M. Boring, A. B. Bronwell, L. E. Grinter, G. A. Rosselot, C. L. Skelley, W. L. Everitt, F. M. Dawson, T. Saville, H. W. Barlow, E. R. Jones, W. W. Dornberger, D. C. Hunt, W. E. Street, C. A. Brown, K. McEachron, E. R. Stapley, L. G. Miller, K. Wendt, W. H. Carson, and B. Bowen. The meeting was called to order at 7:00 P.M.

Report of the Secretary

The Secretary presented a progress report which summarized some of the current developments of the Society. These included the following:

(a) A Public Relations Committee, under the chairmanship of Professor Richard Schmelzer of Rensselaer Polytechnic Institute, has been appointed to develop a public relations program for ASEE. It is suggested that all information of interest to the public be channeled through this Public Relations Committee for press releases.

(b) Steps are being taken to form a Committee on Textile Engineering in the ASEE.

(c) Dean Lassalle, chairman of the ECAC Committee on International Relations, is endeavoring to obtain active participation of the ASEE in UNESCO. The area of engineering education is the most conspicuous void in the program of UNESCO and, in view of the fact that the international program of the U. S. government calls for substantial technical assistance to foreign countries, it would seem that engineering education should play an important role.

(d) A committee of the Society has been appointed, under the chairmanship of Jesse McKeon, to increase the number of Associate Institutional memberships.

(e) Several Divisions of the Society are planning mid-year meetings. The Cooperative Engineering Division held a meeting at Northwestern University on November 8–10, 1951. The Engineering Drawing Division is planning a meeting in New York on January 23–25, 1952. The Division on Relations with Industry is planning a meeting to be held at MIT on the theme "The Student as an Individual" on February 2, 1952.

(f) The Secretary reported on the Mission on Engineering Education to Japan. This item was summarized in the Minutes of the Executive Board meeting of October 29, 1951, published in the November issue of the JOURNAL OF ENGINEERING EDUCATION, page 185.

(g) The Secretary presented a written progress report from the Teaching Aids Committee. This Committee has appointed reviewing committees which are starting to review teaching aids. Ultimately a bulletin will be published, listing those teaching aids which are considered to be acceptable for engineering instruction. He reported that the evaluation program is causing companies which are planning teaching aids to seek the advice of engineering teachers in the preparation of their teaching aids. This is a collateral benefit which the Committee had hoped to achieve and which would result in substantial improvement in the quality of teaching aids constructed in the future.

Report of the Treasurer

Copies of the final audit and the comparative statement of receipts and disbursements for the period July 1 to November 7 for 1950 and 1951 were presented by the Treasurer. This is reported in the Minutes of the Executive Board meeting, November 14, 1951.

Adequacy and Standards of Engineering Education

President Hollister reported that a committee of ECPD on adequacy and standards of engineering education has made a study of the engineering curricula. This study indicates that some of the older curricular areas have not advanced significantly in the past 40 years, despite the rapid advancement of science and engineering practice. The

committee report also stated that the engineering curricula are not breaching the gap between the fundamental sciences and engineering instruction. The report stated that there is very little difference in curricular subjects of various schools, but the distinguishing characteristics lie in the depth of instruction and in the objectives in respect to the outlook to be achieved. There exists a spectrum of objectives ranging from highly professional programs supported by strong science backgrounds to vocational programs in which only a moderate amount of science is included.

The ECPD committee recommended that a study be undertaken by the ASEE on this subject. In order to carry out this recommendation, President Hollister has written to chairmen of Divisions and Committees of the Society urging them to give attention to an evaluation of the engineering curricula. It is believed that this activity should be undertaken on a Division and institutional level, with a national committee appointed to coordinate and review the programs and findings of the Division and institutional committees. This will constitute one of the principal programs of the Society for the coming year.

Cooperation with High Schools and Junior Colleges

President Hollister proposed that a program be undertaken on a regional level to develop closer working relationships between secondary schools and the engineering colleges. This program would endeavor to: (a) seek an improvement in the quality of education of students entering engineering colleges, (b) discuss with high school and junior college teachers curricular problems, with particular emphasis upon improvement of the teaching of mathematics and the sciences, (c) provide a means of channeling information to the high school principals, teachers, and counselors on the career opportunities for students in the engineering field.

President Hollister emphasized that this program should focus attention upon the educational preparation of the student and not upon educational philosophy in general. This would avoid controversies which might arise in dealing with the nebulous subject of educational philosophy. It was suggested that this program be undertaken by the Sections of the ASEE, with a central committee of the ASEE coordinating the work of the Sections and exchanging information on methods and results. The Sections would be responsible for stimulating conferences and meetings between engineering colleges in their geographical area and high schools and junior colleges.

Committee on Improvement of Teaching

Vice President Grinter summarized the work of the Committee, stating that after the final report has been made the work of the Committee would be transferred to the Division of Educational Methods. This would be a permanent organization for stimulating continuous improvement. The report should be out in time for the Annual Meeting.

Plans for Annual Meeting

The Secretary presented a brief report of the recommendations of the Executive Board relating to the plan for general sessions at the Annual Meeting at Dartmouth, as described in the Minutes of the Executive Board meeting of November 14, 1951. The Secretary also stated that he has urged the Divisions and Committees to submit their complete program information by the first of February, since a considerable amount of liaison work is necessary with the host institution in assigning rooms and also in eliminating conflicts before the preliminary program can be sent to the printer.

The local committees at Dartmouth have been appointed and are drawing up plans for the Annual Meeting.

Report of Coordinating Committee on Relations with the Government

Dean Saville reported that a committee of the EJC had been appointed to advise the National Science Foundation on problems relating to grants in the engineering field. He also stated that Dean Potter is the only active engineering representative on the National Science Foundation Board and that it is extremely important that he be re-appointed on expiration of his term in May 1952. The General Council recommended to Vice President Rosselot that he get the endorsement of the ECRC for Dean Potter's re-appointment and send this to either Mr. Steelman or Mr. Dawson in the White House.

Dean Saville reported that the UMT bill has been given preferential status in Congress and will be discussed within 60 days of the convening of Congress. The Engineering Manpower Commission will probably testify on this bill.

Unity of the Profession

Dean Saville reported to the Council that a great majority of the societies had balloted on the Unity organization, with the largest majority voting for Plan A. The framework of this organization will be a modification of the EJC, details of the organization to be worked out at a later time.

Contract Relations with the Federal Government

Vice President Rosselot reported that the Committee of the ECRC on Contract Relations with the Federal Government, under the chairmanship of Dr. Raymond Woodrow of Princeton University, is endeavoring to get agreement of various government agencies on uniform provisions in research contracts. He stated that difficulties had been encountered by engineering colleges due to the fact that some government agencies were citing special cases of types of contracts and endeavoring to force the same provisions upon other universities. Dr. Woodrow presented a paper on this subject at the Houston meeting of the ASEE.

Summer Schools

The Executive Board has voted to authorise ASEE sponsorship of summer schools proposed by the Electrical Engineering Division, the English Division, and the Civil Engineering Division. The Civil Engineering Division is proposing a summer school in Surveying and Mapping and possibly another on Sanitary Engineering.

Previously the Executive Board had authorized ASEE sponsorship of a summer school proposed by the General Electric Company to demonstrate some of the more successful methods of instruction used in their advanced engineering training program. This program embodies some of the principal recommendations of the Committee on Improvement of Teaching, and the General Council therefore voted that the summer school be sponsored by the Committee on Improvement of Teaching, in cooperation with the General Electric Company.

Enlargement of Secretary's Office

President Hollister reported that steps are being taken to enlarge the Secretary's staff in order to relieve the Secretary of some of the routine work and free part of his time for more important contact work with other engineering and educational societies, governmental agencies, and industry. The following steps will be directed toward this objective:

(a) A study will be made by the Secretary and Treasurer of the projected finances, based upon an enlarged Secretarial staff.

(b) An assistant secretary will be added to the Secretarial staff on a part-time basis to handle the editorial work on the Journal and other Secretarial responsibilities.

(c) The Executive Board has voted an increase of up to $1000 to the Secretary's travel fund, to enable him to attend important meetings and enlarge the contact work with other organizations and government agencies.

(d) The officers are looking ahead to a full-time secretarial appointment instead of a part-time appointment as in the past.

(e) It is anticipated that the expansion of the Associate Institutional memberships in the Society will defray part of the expense of this change.

Committee of General Council to Report on Activities of the Council

A Committee of the General Council, consisting of H. W. Barlow, Chairman, Eric Walker and L. G. Miller, was appointed to prepare recommendations on methods of expanding the activities of the General Council. The General Council has been largely a policy decision body, which acts upon proposals submitted by Divisions and Committees of the Society or individuals. It has been suggested that the Council members could take a more direct part in the operations of the Society.

Resolution of the Engineering Drawing Division

Professor Street, representing the Engineering Drawing Division, presented a resolution of the Engineering Drawing Division. This resolution was addressed to the Executive Board of the ASEE and proposed that the Executive Board forward it to the Committee on Engineering Schools of the ECPD. It recommended in effect, that in view of the importance of engineering drawing in the

engineering curricula, that ECPD visitation committees should seek the assistance of competent drawing teachers in evaluating the quality of instruction in engineering drawing for engineering curricula accreditation purposes. Dean Dawson moved that the resolution be referred to the Executive Board for study and report back to the Council. The motion was passed.

Life Memberships

The following were voted to life membership in the Society: H. L. Creek, C. H. Mathewson, L. Mitchell, B. J. Robertson, R. J. Streubel, W. C. Taylor, K. O. Thompson.

Respectfully submitted,
ARTHUR BRONWELL
Secretary

College Notes

William Gardner Van Note was installed as the ninth president of **Clarkson College of Technology.** Dr. Van Note was formerly at North Carolina State University at Raleigh.

Charles W. MacGregor, professor of applied mechanics and head of the materials division at Massachusetts Institute of Technology, has been named vice-president of the **University of Pennsylvania** in charge of engineering and scientific studies, President Harold E. Stassen of the University announced last night. In the office at Pennsylvania, newly-created by the trustees, Dr. MacGregor will have jurisdiction over the engineering and scientific departments of the University. His administration will also include the Towne Scientific School and the Moore School of Electrical Engineering.

ANNUAL MEETING

June 23–27, 1952

Dartmouth College **Hanover, N.H.**

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Pennsylvania State College	April 18–19, 1952	E. B. Stavely, Pennsylvania State College
Illinois-Indiana	University of Illinois	May 17, 1952	D. G. Ryan, University of Illinois
Kansas-Nebraska	University of Nebraska	Nov. 16–17, 1951	Kenneth Rose, University of Kansas
Michigan	University of Detroit	May 10, 1952	W. P. Godfrey, University of Detroit
Middle Atlantic	Newark College of Engineering	December, 1951	S. J. Tracy, Jr., City College of New York
Missouri	University of Arkansas	April 5, 1952	R. Z. Williams, Missouri School of Mines
National Capital Area	Howard University George Washington University	February 5, 1952	W. Oncken, Jr., Bureau of Ordnance
New England	Worcester Polytechnic Institute	Oct. 18, 1952	E. T. Donovan, University of New Hampshire
North Midwest	Iowa State College	Oct. 3–4, 1952	S. J. Chamberlin, Iowa State College
*Ohio	Ohio State University		W. F. Brown, University of Toledo
Pacific Northwest	University of Washington	May 23–24, 1952	T. H. Campbell, University of Washington
Pacific Southwest	University of Nevada	Dec. 27–28, 1951	S. F. Duncan, University of Southern California
*Rocky Mountain	University of Wyoming		E. J. Lindahl, University of Wyoming
Southeastern	Clemson College	April 10, 11, 12, 1952.	R. L. Sumwalt, University of South Carolina
Southwestern	University of Houston	April 11 & 12, 1952	H. P. Adams, Oklahoma A. & M. College
Upper New York	Alfred University	October 10–11, 1952	R. M. Campbell, Alfred University

Members of the Society are welcome at all Section Meetings

* No Date Set.

In the News

ASEE Solicits Teaching Aids

The American Society for Engineering Education is issuing a call to industry, the professional societies, public or private research organizations, and the engineering colleges for teaching aids which may be reviewed in its forthcoming "Catalog of Teaching Aids." This publication, which is being prepared by the Society through its Committee on Teaching Aids, will contain reviews of all kinds of teaching aids suitable for use in the teaching of various engineering subjects. The first edition of the catalog will be limited to civil, electrical, and mechanical engineering, mathematics, and engineering mechanics. This edition will also be limited to motion picture films (sound and silent), slides in 2×2 in. or $3\frac{1}{4} \times 4$ in. size, models, charts, and exhibits. Information on such devices should be sent to Professor Carl W. Muhlenbruch, Chairman ASEE Committee on Teaching Aids, Northwestern Technological Institute, Evanston, Illinois, who will see that they reach the proper reviewing group. Each offer of a teaching aid should be accompanied by a written description or photograph and a set of operating instructions.

The chief purpose of the ASEE "Catalog of Teaching Aids" will be to help the engineering teacher choose those teaching aids which most suit his particular needs and to provide him with the assurance that they have been passed upon by competent individuals. The catalog, which is to be sold at a nominal price, will include a brief description of each teaching aid and a review prepared by a committee of three qualified educators in the field for which it is intended. The listing will also indicate where the device may be obtained, its dimensions, important physical characteristics, any charge for its use, and other detail information which the prospective user would require.

It is expected that the catalog will show industry what engineering educators want in the way of teaching aids. Any organization setting out to make teaching aids will have only to study the reviews contained in the catalog to learn what type of teaching aids the colleges need. It can then use this information as a basis for planning its own contributions to the field. The Committee asks that teaching aids, not "training aids," be submitted for review in the catalog. The training aid has its uses in teaching workers in industry how to perform certain manual operations, but in educating engineers it is necessary to provide the student with an understanding of the fundamentals of the subject being studied. For this reason the training aid is not applicable to engineering education. Instead, what is needed are teaching aids, which enable the student to grasp more quickly the fundamentals of the science of engineering and then to apply them to the solution of actual problems.

At the same time, it is necessary that the teaching aid do more than entertain or just use up time. In order to be really effective, teaching aids must encourage and help the student carry out the learning process himself. A teaching aid must perform either of two important services. The first of these is to enable the teacher to present information more rapidly and thoroughly than could be done without the device. An example of this would be a set of color slides on the steel making process. If it is not possible to take the students on an actual tour of a steel mill, this photographic presentation will convey a fuller picture and will require less time than would any word description the instructor might give. The other important function of the teaching aid is to help the student understand a process which could not be presented adequately in another way. Thus the "time microscope," or high-speed motion picture, is a valuable aid in analyzing the action of high speed machinery or the phenomena of cavitation.

National Science Foundation News

Graduate Fellowships in Science

Approximately 400 graduate fellowships will be awarded by the National Science Foundation for the academic year 1952–53 in the mathematical, physical, medical, biological and engineering sciences. Fellows may elect to receive training in fields which combine two or more of these sciences, such as medical physics or physical anthropology. No awards will be made for study in clinical medicine, although applications will be considered from medical students who wish to prepare for careers in medical research.

The majority of National Science Foundation Fellowships will be given to predoctoral applicants, particularly to those who will be eligible to begin graduate study during the coming year. Predoctoral Fellows will be selected on the basis of ability, determined by means of scores made on tests of scientific aptitude and achievement, academic records, and recommendations regarding each candidate's abilities. The testing and evaluation of applicants will be carried on by the National Research Council. Final selection will be made by the National Science Board of the National Science Foundation. A limited number of postdoctoral Fellowships will also be awarded.

Application forms for National Science Foundation Graduate Fellowships are available from the Fellowship Office, National Research Council, Washington 25, D. C. In order to be considered for the 1952–53 academic year, completed applications must be returned to the Fellowship Office, National Research Council, by January 7, 1952. The affidavit and loyalty oath required by the National Science Foundation Act of 1950 will constitute part of the application form and must be completed and returned with other application materials.

New Chairman

Chester I. Barnard, president of the Rockefeller Foundation, was elected chairman of the **National Science Board of the National Science Foundation** at its second annual meeting. Mr. Barnard succeeds James B. Conant, president of Harvard University, who was the first chairman of the Board, elected to serve the initial term. Edwin B. Fred, president of the University of Wisconsin, was re-elected vice chairman of the National Science Board. The new chairman and vice chairman were elected for two-year terms of office as prescribed by the National Science Foundation Act of 1950. Four members of the Executive Committee, whose terms had expired, were also re-elected. These were: Mr. Barnard; Detlev Bronk, president of the Johns Hopkins University and president of the National Academy of Sciences; Lee A. DuBridge, president of the California Institute of Technology; and Elvin C. Stakman, chief of the Division of Plant Pathology and Botany at the University of Minnesota.

Research Proposals

The first draft of a guide to assist scientific research investigators in the preparation of proposals for National Science Foundation research grants has been issued by the Foundation. Copies of the guide will be distributed widely to universities and colleges, laboratories, and other organizations in a position to carry on competent scientific research. The Foundation will support basic research in

the mathematical, physical, medical, biological and engineering sciences, by making grants for such research to educational, industrial, governmental or other institutions, or individuals. Ordinarily grants will be awarded to institutions for research by specified individuals. In reviewing proposals the Foundation will emphasize the scientific merit of the suggested research, including the competence of the scientist under whom the study will be made.

Summer Schools

The Executive Board of the ASEE has authorized sponsorship of summer schools proposed by the Electrical Engineering Division and the English Division. Both summer schools will be held at Dartmouth College preceding the Annual Meeting.

The theme for the Electrical Engineering Division Summer School will be "Undergraduate Teaching of Electrical Circuits and Fields." It will be held on June 20 and 21, 1952, and the registration fee will be $1.50. For further information, address Dr. J. D. Ryder, Electrical Engineering Department, University of Illinois, Urbana, Illinois.

A summer school on Sanitary Engineering has been proposed by the Civil Engineering Division.

New Members

ABBOTT, JOHN P., Dean of Arts and Sciences, Texas A & M College, College Station, Texas. H. W. Barlow, A. B. Bronwell.

ABRAMOWITZ, ABRAHAM, Assistant Professor of Electrical Engineering, City College of New York, New York, N. Y. Harold Wolf, Vincent Deltoro.

BARD, ROBERT E., Associate Professor of Electrical Engineering, Fournier Institute of Technology, Lemont, Ill. J. D. Ryan, A. B. Bronwell.

BATEMAN, RICHARD M., Director, Purdue University Center, Fort Wayne, Indiana. C. W. Beese, Maurice Graney.

BILLINGSLEY, JOHN D., Professor of Ordnance, U. S. Military Academy, West Point, N. Y. O. J. Gatchell, E. R. Heiberg.

BROWN, CHANDLER W., Instructor in Civil Engineering, Duke University, Durham, N. Carolina. W. B. Snow, H. C. Bird.

CAMPBELL, BONHAM, Lecturer in Engineering, University of California, Los Angeles, Calif. L. M. K. Boelter, C. M. Duke.

CARLEY, WILLIAM J., Assistant Professor of Civil Engineering, Clarkson College of Technology, Potsdam, New York. W. H. Allison, L. W. Herron.

CLARK HERBERT M., Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y. P. E. Hemke, R. S. Poor.

DREVDAHL, ELMER R., JR., Assistant Professor of Mining Engineering, South Dakota School of Mines & Technology, Rapid City, S. D. L. E. Shaffer, W. E. Wilson.

DURHAM, FRANKLIN P., Assistant Professor of Aero. Engineering, University of Colorado, Boulder, Colo. K. D. Wood, W. C. DuVall.

EDWARDS, JAMES L., Assistant Professor of Mechanical Engineering, Clemson Agricultural College, Clemson, S. C. D. W. Bradbury, J. E. Shigley.

FUTRAL, SAMUEL M., JR., Instructor in Engineering Drawing, Northwestern University, Evanston, Ill. Raymond Kliphardt, M. B. Lagaard.

GADBOW, VINCENT L., Instructor in English and Social Sciences, South Dakota School of Mines & Tech., Rapid City, S. D. C. M. Rowe, E. E. Clark.

GROGAN, PAUL J., Chairman, Department of Engineering, University Extension Division, University of Wisconsin, Madison, Wisconsin. K. F. Wendt, B. G. Elliott.

HARLEY, JOHN D., Professor of Engineering, A. & I. State University, Nashville, Tenn. B. L. Dutton, W. C. McNeill.

HENDERSON, CHARLES, Dean of Engineering, University of Virginia, Charlottesville, Va. E. C. McClintock, H. L. Kinnier.

HINEBAUGH, MYRON E., Instructor in Electrical Engineering, University of Tennessee, Martin Branch, Martin, Tenn. J. O. Jones, W. C. Taylor, Jr.

IRWIN, HARRY H., Professor of Mathematics, Washington State College, Pullman, Wash. H. F. Lickey, E. G. Ericson.

JONES, DANIEL W. B., Instructor in Civil and Architectural Engineering, University of Colorado, Boulder, Colo. M. W. Jackson, R. E. Rathburn.

KAUFMANN, FRED H., Professor of Economics, Milwaukee School of Engineering, Milwaukee, Wis. F. J. Van Zeeland, E. E. Petty.

KEEHNER, JOHN B., Instructor in Physics, Science Dept., General Motors Institute, Flint, Michigan. H. M. Dent, C. A. Brown.

KIRCHNER, JAMES W., Acting Instructor in Electrical Engineering, Ohio University, Athens, Ohio. E. J. Taylor, P. H. Black.

LAPRADE, GEORGE L., Instructor in Science Dept., General Motors Institute, Flint, Mich. H. M. Dent, C. A. Brown.

LINSLEY, RAY K., Associate Professor of Civil Engineering, Stanford University, Stanford, Calif. B. M. Green, E. L. Grant.

LOGAN, LELAND, Instructor in Engineering, Champlain College, State University of New York, Plattsburg, N. Y. S. C. Allen, E. S. B. Litkin.

LYMAN, JOHN R., Instructor in Mechanical Engineering, University of Maine, Orono, Maine, J. F. Lee, A. S. Weaver.

MANCILL, JULIAN D., Professor of Mathematics, University of Alabama, Tusca-

loosa, Ala. (On leave: Redstone Arsenal —in charge of graduate training in engineering—Huntsville, Ala.) H. Kuenzel, C. H. Bryan.

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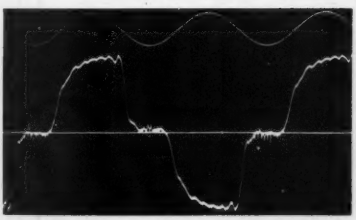

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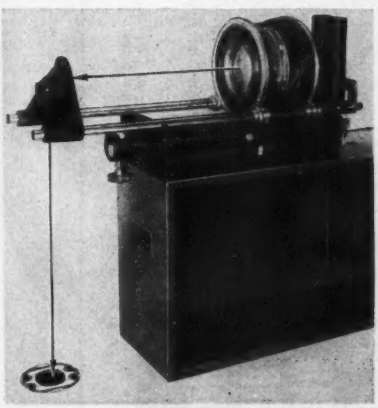

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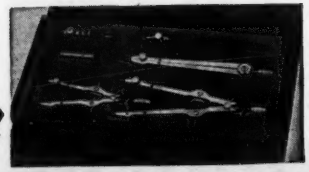

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